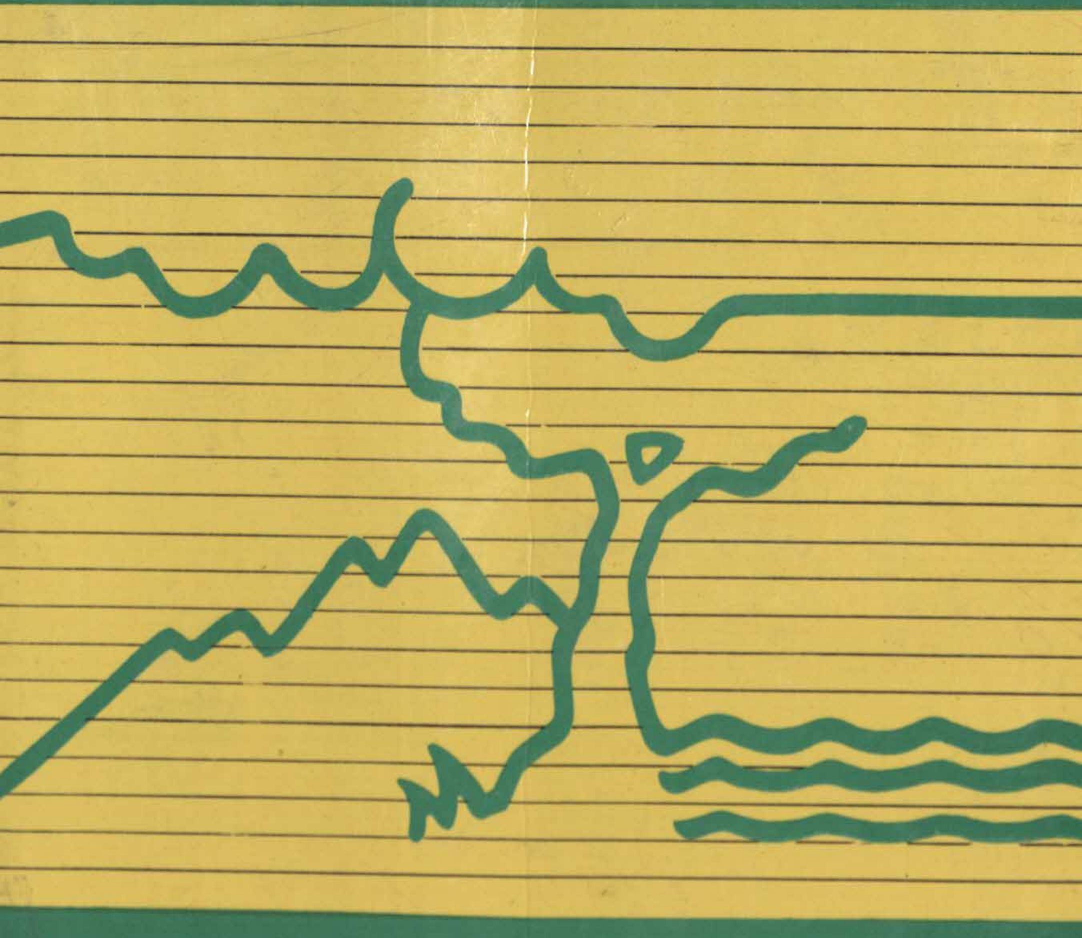
Perspectives in Environmental Management



Editor T. N. Khoshoo

PERSPECTIVES IN ENVIRONMENTAL MANAGEMENT

PERSPECTIVES IN ENVIRONMENTAL MANAGEMENT

Addresses Delivered at the 73rd Session of the Indian Science Congress

Editor
T.N. KHOSHOO

OXFORD & IBH PUBLISHING CO. PVT. LTD.
New Delhi Bombay Calcutta

372.3
KHO

© 1987 Indian Science Congress Association

ISBN 81-204-0248-0

Published by Mohan Primlani for Oxford & IBH Publishing Co. Pvt. Ltd.,
66 Janpath, New Delhi 110001 and printed at Printsman Press, Faridabad

This volume is respectfully dedicated to
Dr. B.P. Pal, FNA, FRS
former Director General,
Indian Council of Agricultural Research
and
former Chairman
National Committee on
Environmental Planning and Coordination
Government of India
for his contributions to crop improvement and agriculture,
and
environmental science and technology

Preface

Not too long ago environment used to be the concern only of sanitary and public health engineers. However, at present the widening frontiers of environmental research and development have clearly shown that the area is indeed interdisciplinary and trans-sectoral. The environmental sciences include all the basic and applied sciences, all forms of engineering, social and economic sciences, and ethics and law. In our own country, the late Prime Minister Mrs. Indira Gandhi recognised the tremendous role life-scientists could play in the area of environmental management. Such a belief stemmed from the fact that "environment is for *all the living creatures*, of which human being is one". Among living creatures, the prime environmental offender is humankind itself through its actions, which, in course of time, make human beings and other creatures environmental victims. In other words, a victim of his own actions. Humankind has reaped tremendous short-term economic benefits by reckless utilisation of natural resources and has passed the long-term environmental costs to the succeeding generations. Thus even though development without concern for the environment is instrumental for mounting pollution and eco-degradation, development is the very means to lift our teeming millions out of the widespread and historic poverty so as to assure them a minimum standard of living. Making development free of pollution and ecodegradation requires both scientific and technological inputs. For successful implementation of environmental programmes, we need not only research and development, but also education and training, and demonstration and extension.

With some of these things in mind, the Indian Science Congress Association decided in January 1985 to have "Science and Technology in Environmental Management" as the focal theme of the Seventy-third Session (January 3 to 7, 1986) at the Delhi University.

The present volume contains selected addresses relevant to the theme. In all, 33 papers are included here which have been arranged in eight sections. The volume starts with the Inaugural Address by Mr. R.V. Venkataraman, President of India, (at the time of the Congress he was Vice-President) and ends with the Concluding Address by Mr. Rajiv Gandhi, Prime Minister of India. In between, there are 31 papers under Mathematical, Physical and

Chemical, Biological, Health, and Energy and Engineering Sciences. Five papers discuss the common issues of the State of the Indian/Global Environment.

The papers adopt one of the two major approaches, namely, a Restorative or Curative approach for setting right the backlog of past ecological "sins", and a Preventive approach to insulate the country from future environmental damage.

Today, there is no longer the need to restate the problems. Their causes and remedial measures are well known and well understood. Today, the main problem is to make development sustainable by wise management of resources. Furthermore, not only is the social equity between various sections of our society important, but equally, if not more, important is the intergenerational equity between this and the succeeding generations. Thus there is a need to look deeply into wisdom behind the decisions we take that are likely to affect the well-being of our future generations for better or for worse.

A nation such as ours is reasonably resource-rich but technology-poor and has increasing demands on its resources by the escalating population. Such a nation cannot be unmindful to the erosion in the shrinking resource base. The only way it can ensure sustainability is by the introduction of environmental parameters in the entire gamut of planning process in all sectors like, landuse, agriculture, forestry, water-use including irrigation, mining, industrial development, human settlements, tourism, etc.

We can significantly reduce the adverse effect of development on environment through proper environmental impact analyses which in turn must lead to controlling such effects on ecosystems by proper resource management techniques.

At the end of the book is given a set of recommendations which highlights the importance of long-range environmental security and, therefore, also of developmental security.

It is hoped that this volume would prove to be of value to students, teachers, planners, managers and policy makers in the area of environment.

I thank Dr. R.K. Pachauri for facilities.

T.N. Khoshoo
General President
73rd Session
Indian Science Congress

Tata Energy Research Institute
7, Jor Bagh
New Delhi 110003

Contents

Preface: T.N. Khoshoo vii
List of Contributors xiii

I INAUGURAL SESSION

1. Inaugural Address 3
R.V. Venkataraman
2. Environmental priorities in India and sustainable development 10
T.N. Khoshoo

II MATHEMATICAL SCIENCES

3. Perspectives on applied mathematical modelling with special reference to atmospheric-oceanic and physiological sciences 27
M.P. Singh
4. Present trends and future directions of statistics in India 50
G. Sankaranarayanan

III PHYSICAL AND CHEMICAL SCIENCES

5. Lasers and some of their applications 71
P.S. Narayanan
6. Chemistry in the solution of environment pollution 78
M.M. Taqui Khan

IV BIOLOGICAL SCIENCES

7. Optimizing soil environment for sustained agricultural production 95
N.N. Goswami
8. Some stressed habitats, functioning of their communities and proper management 116
L.P. Mall
9. Plant research and world agriculture 141
M.S. Swaminathan

10. Tropical forests, environment and development 157
M.K. Muthoo
11. The structure, dynamics, and rehabilitation of drastically disturbed ecosystems 163
Mohan K. Wali
12. Current research on forest biology in India and its implications for social forestry and agroforestry practices 184
Peter S. Ashton
13. Watershed management in the Indian Himalaya 203
K.G. Tejwani
14. Cell biology and monitoring of environment 228
A.K. Sharma
15. Useful management of electropollution caused by low level microwave radiations in single cell microorganisms 234
S.K. Dutta, S. Mohammed and I. Sheikh
16. Genetics, culture and environment in tribal health in India 255
S.C. Tiwari

V HEALTH SCIENCES

17. Perspectives in urban health in India 275
V. Ramalingaswami
18. Nutrition and brain 283
P.N. Tandon
19. Environmental factors affecting human work performance 288
J. Sen Gupta
20. Psychological dimensions of environmental management 303
Uma Shanker
21. Physiological and medical problems of man underwater 320
A.K. Chatterjee

VI ENERGY AND ENGINEERING SCIENCES

22. Energy in the world 335
Hermann Bondi
23. New energy technologies for entering the twenty-first century 341
Maheshwar Dayal
24. Fossil fuels use, society and the environment 353
R.K. Pachauri
25. Technology adaptation for community development 361
M.M. Chakrabarty
26. Industrial environment in India 374
S.S. Ramaswamy

VII STATE OF THE ENVIRONMENT

27. Some considerations on the state of the present climate and environment in India—An essay in 'decline and fall' 391
S. Dillon Ripley
28. Environmental management in Asia and the Pacific and the role of science and technology 401
ESCAP
29. World commission on environment and development 423
Jim MacNeill
30. The status of environment and development of environmental science and technology in China 431
Lu Jiaxi and Liu Jingyi
31. The global economic-environment interdependence 439
Asit K. Biswas

VIII CONCLUDING SESSION

32. Report by the President 457
T.N. Khoshoo
33. Indian science must be equal to the best 461
Rajiv Gandhi
34. Recommendations on the focal theme 466

Index 477

List of Contributors

1. Mr. R.V. Venkataraman
   President of India
   New Delhi

2. Mr. Rajiv Gandhi
   Prime Minister of India
   New Delhi

3. Dr. T.N. Khoshoo
   President, Indian Science Congress Association
   Distinguished Scientist (CSIR)
   Tata Energy Research Institute
   7 Jor Bagh
   New Delhi 110003

4. Dr. Peter S. Ashton
   Director, Arnold Arboretum,
   Harvard University
   Cambridge, Massachusetts 02138, U.S.A.

5. Dr. Asit.K. Biswas
   President, International Society for Ecological Modelling
   76 Woodstock Close
   Oxford, U.K.

6. Prof. Sir Hermann Bondi
   Chairman
   National Environment Research Council
   Churchil College
   Cambridge CB 3 ODS, U.K.

7. Prof. M.M. Chakrabarty
   Vice Chancellor
   Jadavpur University
   Calcutta

8. Surg. Capt. A.K. Chatterjee
   INHS, ASVINI
   Colaba
   Bombay 400005

9. Dr. Maheshwar Dayal
Secretary
Department of Non-Conventional Energy Sources
CGO Complex, Lodi Road
New Delhi 110003

10. Prof. S.K. Dutta
Professor of Molecular Genetics
Department of Botany, Genetics and Human Oncology
Howard University
Washington DC, U.S.A.

11. Dr. N.N. Goswami
Head
Division of Soil Science & Agricultural Chemistry
Indian Agricultural Research Institute
Pusa, New Delhi 110012

12. Prof. Lu Jiaxi
President
Chinese Academy of Sciences, Academia Sinica
Beijing, China

13. Dr. Liu Jingyi
Academia Sinica
Beijing, China

14. Mr. Jim MacNeill
Secretary General
World Commission on Environment and Development
Plais Wilson
Geneva, Switzerland

15. Dr. M.K. Muthoo
Director
Forestry Operations, Food and Agriculture Organisation
Rome, Italy

16. Prof. P.S. Narayanan
Chairman
Division of Physics & Mathematics Sciences
Department of Physics
Indian Institute of Science
Bangalore 560012

17. Dr. R.K. Pachauri
Director
Tata Energy Research Institute
7 Jor Bagh
New Delhi 110003

18. Prof. L.P. Mall
Consultant
Department of Environmental Sciences
College of Basic Sciences and Humanities
G.B. Pant University of Agriculture & Technology
Pantnagar 263145

19. Prof. V. Ramalingaswamy
Director General
Indian Council of Medical Research
Ansari Road
New Delhi

20. Dr. S.S. Ramaswamy
Former Director-General
Factory Advice Service and Labour Institutes
Bombay

21. Prof. S. Dillon Ripley
Secretary Emeritus
Smithsonian Institution
Washington DC, U.S.A.

22. Dr. J. Sen Gupta
Deputy Director
Defence Institute of Physiology & Allied Sciences
Delhi Cantt

23. Dr. Uma Shanker
Senior Faculty Member
Management Development Institute
Jeevan Tara Building
5 Parliament Street
New Delhi 110001

24. Prof. G. Sankaranarayanan
Head
Department of Mathematics
Annamalainagar, Tamil Nadu

25. Prof. A.K. Sharma
Department of Botany
35 Ballugunge Circular Road
Calcutta 700019

26. Prof. M.P. Singh
Head
Centre for Atmospheric and Fluid Sciences
Department of Mathematics
Indian Institute of Technology, Hauz Khas
New Delhi 110016

27. Dr. M.S. Swaminathan
Director General
International Rice Research Institute
Manila, Philippines

28. Prof. P.N. Tandon
Professor of Neurosurgery
All India Institute of Medical Sciences
Ansari Nagar
New Delhi 110029

29. Prof. M.M. Taqui Khan
    Director
    Central Salt & Marine Chemicals Research Institute
    Gijubhai Badheka Marg
    Bhavnagar, Gujarat

30. Dr. K.G. Tejwani
    Resident Consultant
    International Centre for Integrated Mountain Development
    Kathmandu, Nepal

31. Prof. S.C. Tiwari
    Head
    Department of Anthropology
    University of Delhi
    Delhi 110007

32. Prof. Mohan K. Wali
    State University of New York
    College of Environmental Science and Forestry
    Syracuse
    New York, U.S.A.

I

INAUGURAL SESSION

1

Inaugural Address

R.V. Venkataraman

I am very happy to join you at the annual gathering of the most representative body of Indian scientists, young and old, fresh and experienced. For many young scientists this is perhaps the first occasion to interact with well-known experts, whose names they have heard and whom they have admired. The older scientists will find their contact with young minds, full of great aspirations ane brave new ideas, refreshing. I am sure that this interaction of experience and freshness of approach will lead to fruitful developments. The significance of such meets of questing creative minds from various areas of science cannot be over-emphasized.

We in India have a long tradition of science and technology, going back to the Indus Valley civilization which flourished about 5,000 years ago. Our ancestors had a spirit of enquiry and a desire to know and to understand. They asked questions, made speculations, undertook observations and analyzed the data collected by them. These, as we all know, are basic ingredients of the scientific temper and scientific method.

The world is aware of India's contribution of the place value of a digit and a digit without value, which by proper placement can increase or decrease the values of other digits manifold; a contribution without which the large-scale calculations needed by an industrial society would be unthinkable. But it is often forgotten that this great contribution was not made in isolation. Significant contributions have been made in our country in areas of astronomy, mathematics, medicine, chemistry, metallurgy, architecture, and engineering. We are rightly proud of Aryabhata (fifth century A.D.), Varahamira (sixth century A.D.) and Bhaskara (twelfth century A.D.). While these developments were taking place inside India there is also evidence of vigorous interaction with other countries. Many Indian works were translated into Persian and Arabic to facilitate the flow of knowledge from India to other countries. In the reverse direction knowledge developed elsewhere was assimilated by our scholars. The names of Alberouni, Abu Sinna etc., are familiar to Indian Science.

With the advent of the Industrial Revolution in Europe, our country got separated from the mainstream. In fact the fruits of the Revolution got concentrated in the North and West and the world got divided into two distinct parts—the developed and the less developed—with India falling in the latter category. Due to disparities of resources, and skills necessary to exploit them, the gap between the developed and the less developed went on increasing with the passage of time. Even now the developed countries of North America, Europe, Japan and Australia consume nearly half of the world's resources for industrial growth, while their population is less than one quarter of the total world population.

Towards the end of the last century and the beginning of this, India started taking steps to get into the world of Modern Science and Technology. The Indian Association for the Cultivation of Science was founded by Mahendra Lal Sircar in 1876. The Haffkine Institute of Bombay was founded in 1899 and the Pasteur Institute at Kasauli in 1900. The Geological Survey of India, Pusa Institute of Agriculture, and other institutions devoted to research and training were started. Indian scientists like J.C. Bose, P.C. Ray, S. Ramanujan, C.V. Raman, Birbal Sahni, S.N. Bose, Megnath Saha, H.J. Bhabha, K.S. Krishnan and others made contributions of international standards. Simultaneous with this resurgence of Indian Science, the Indian Independence movement came to the conclusion that the country will need a strong base of Science and Technology, if solutions to the problems of hunger and want of our people were to be found. The expectations of the people from science were articulated by various spokesmen of the Indian Independence movement, the most effective of whom was Jawaharlal Nehru, with his firm faith in Science and Technology as the fundamental instruments of human welfare. In fact he was of the view that "it is science alone that can solve the problem of hunger and poverty.... The future belongs to science and to those who make friends with science". You recognized his contributions by electing him your general President first for the 1943 session, which he could not attend because he was in jail, and then in 1947 when he presided over the 34th session at Delhi.

After independence, the government led by Jawaharlal Nehru, started developing a Science and Technology base in a conscious way to serve as a means for social and economic change. National laboratories were set up, brilliant scholars were trained in the best institutions of the world, and universities were encouraged to regard research as their major responsibility. The Atomic Energy Commission and Space Research Organisation came up. The

Technology Policy Statement of the Government of India released at the 1983 session of this Congress, states: "The use and development of Technology must relate to the people's aspirations. Our own immediate needs in India are the attainment of technological self-reliance, a swift and tangible improvement in the conditions of the weakest sections of the population and the speedy development of backward regions. We seek technological advancement not for prestige or aggrandisement, but to solve our multifarious problems and to be able to safeguard our independence and. our unity . . "

Many of you look upon the pursuit of science as a pursuit of truth and knowledge, independent of its relevance or utility. But in my view, there is no contradiction between pursuit of science for the understanding of the natural phenomena or forces, and using this understanding for the welfare of our people.

Science has given to mankind deep understanding of natural phenomena and knowledge of and access to great sources of energy and power. However, the wisdom of our species has not kept up with the achievements of science. Whereas the means of power, communication and knowledge of biological processes, including those concerned with the production of food, could have been used to remove hunger and poverty, to remove barriers of race, colour, national borders, etc., these powerful resources have been diverted to unproductive destructive things like nuclear armaments, chemical and biological weapons and perhaps space wars. A situation has arisen where the stockpiling of nuclear weapons fills the mind with terror. An accident, misjudgment or irresponsible action can bring about holocaust resulting in a perpetual cold night on earth converting our planet into a piece of radioactive cold matter where no life can survive. No nation or individual, however powerful or wise, has a right to hold the human race to ransom. The means that science has put at our disposal should be used to build bridges. No one has a right to destroy life on Earth.

Mankind not only has a right to life but it has a right to a good life of quality, free of squalor, disease and deprivation.

An important factor for quality of life is the environment in which a species exists; it depends very much on the ecological balance and can be badly impaired by pollution, natural or man-made. Man is himself a part of his environment and ecology and any change in his numbers, habits or quality affects the total natural environment. As the late Shrimati Indira Gandhi once said, "The Indian tradition teaches us that all forms of life—human, animal, and plant—are so closely interlinked that disturbance in one gives rise to imbalance in the others."

The rate of growth of population is very alarming indeed. In the beginning of this century our population was about 1.5 billion and by the year 1970, it had more than doubled, reaching approximately the 3.6 billion mark. If, therefore, we continue with this performance in the years to come, we are bound to number about 6 billion at the turn of the new century which is less than two decades away.

To meet the needs of increasing population, our forests, which used to give shelter to such graceful animals as lions and tigers, are now being cut down and the wood so obtained is used either as fuel or for building our own houses. Thus, when the rains come we have soil erosion, there being no plant roots to keep the soil intact. Due to unplanned urbanization, we have already seen limits to which resource availability is being stretched in some of our urban centres. The over-exploitation of our forest-resources has brought down our resource-base to a meagre 12 per cent of forest cover, at present. This type of continuous soil erosion is responsible for the silting of our streams, rivers and lakes. As a result of silting, the water becomes opaque and thus reduces photosynthesis which is so essential for plant life. With the destruction of our aquatic plants, the fishes which feed on them, will also perish. Even otherwise, these acquatic plants and animals find it difficult to live because of the various inorganic chemicals which are being constantly drained into our lakes and rivers. Effluents from our industrial establishments like the lead and zinc works, tanneries, breweries, paper mills, gas plants and mines, add their share of filth to the air, water and atmosphere. Our waters are also being polluted daily with organic chemicals found in the municipal sewage and drainage from the large agricultural farms. Sometimes, it so happens that the pumping station for the supply of drinking water is located near sewage works leading to the mixing of the two. Our drinking water, thus, becomes polluted resulting in various human diseases.

Similarly, the air we breathe is also being constantly polluted by the smoke coming out of our chimneys and also from the exhaust pipes of our vehicles which are themselves increasing daily resulting in various diseases of lungs and throat. The tragedies of Bhopal and (fortunately at a lesser scale) at Delhi were caused by leakage of poisonous gases into the air we breathe.

Then at places where some of our thermal plants and atomic reactors are located, another type of pollution is taking place. The hot water which is being pumped out of such establishments is not only destroying the aquatic plants and animals, but is also responsible for the rise in our atmospheric temperature. The heat generated by our industrial units is also doing the same and if this goes on there it may be that one day when even the icy polar caps in the Arctic and the Antarctic regions will start to thaw. The resulting rise in sea level may threaten the big cities located on the sea coast.

Noise produced by the latest jet aeroplanes is said to be injurious to the health of persons living near the big international airports. In fact, the noise produced by the loud-speakers at fairs, festivals and weddings disturb the sleep of persons all round the area and this is one of the health hazards which needs our attention immediately.

The sturdy farmers of the Punjab have brought about a Green Revolution in the country by sowing the seeds of some of the dwarf varieties of wheat imported from Mexico. With this we have become self-sufficient in our own requirements of food grains. Similarly, the recent White Revolution has provided more of rice, milk and eggs for our growing population. Even the Blue Revolution which we are going to have now will provide us more of protein in the form of fish. All this has been possible because we have at our disposal a large number of chemicals in the form of insecticides, pesticides, weedicides and fungicides. But we do not yet know adequately the effects of these on the non-target organisms, including human beings.

Developmental activities are essential for the economic progress of our country. But all developmental activities have their own positive and negative aspects for the maintenance of an ecological balance. The strategy adopted, obviously aims just at conserving resources, their rational use, with a minimal adverse impact on the system. Our past experience has shown that mismanagement, whether it be of a forest, land, or of water, has resulted in longer-term problems. Also, we did not foresee some of the problems that have resulted from industrialization. However, if environmental degradation is to be arrested and reversed, dynamic and thoughtful management would have to be woven into our industrial fabric and culture. The management perspectives should aim to:

—Preserve what needs to be conserved;
—Protect what needs to be protected;
—Regulate exploitation to acceptable limits; and
—Assess the absorptive capacity of the environment to take adverse impacts.

An approach based on the above will be able to protect and deliver to future generations what we had inherited from our forefathers.

Concerned by the phenomenal growth of population and the pollution caused by industrial growth, there is a growing opinion that there must be an end to growth. These neo-Malthusians accept the conclusions of the Club of Rome report. The limits of growth, the pattern of steady growth that has characterized the developed world since the Industrial Revolution must come to an end. According to them, the resources that have sustained development are not inexhaustible and the share of the developing world in them will always be less than adequate. They also argue that growth has brought about not only pollution of the environment which has affected the quality of life, but also another type of pollution in the form of pressures of competitive society in which human relations suffer and there is a tendency to produce social, psychological and biological morbidities.

The pessimism of the neo-Malthusians is not shared by many others, who feel that a Middle Way is possible. They feel that we shall be able to discover and locate other resources. According to Norman Macrae, scientific knowledge and technological development have been proceeding exponentially and continuing rapid advances will solve the problems of pollution and limited resources. In his assessment, the poorer two-thirds of mankind could in the next 70 years be raised from intolerable indigence to something better than the comfortable affluence enjoyed by the other one-third. He states that it is probable that during at least our children's life times, human invention and innovation will acquire extraordinary new abilities to control natural phenomena, to draw all the energy we need from the fusion process that will utilize the waters of the oceans as a limitless reservoir and understand the processes of putting together matter molecule by molecule in such a way that environment is not subjected to pollution. AU.N. Committee headed by Nobel Laureate Wassily Liontief reported in 1976 that "World resources will be sufficient to support a growing population and higher living standards without inevitable environmental damage." According to them, the present drawbacks are not scarce resources or the inevitability of environmental pollution by industrial processes, but political and institutional deficiencies. "Development without destruction" is the theme of a conservation strategy launched worldwide which aims at protecting the resource-base and utilizing it in a rational manner for sustained development. The Government of India has been sensitive to environmental concerns from the very beginning and has initiated several initiatives with the overall objective of ensuring environmental protection and conservation. Within the last two decades, concepts have been formulated and Water and Air Acts have been enacted to deal with the pollution problem. We have realized that technology and advancement are essential for progress but we must use them for creating a better environment. It is important to realize that there is nothing wrong with the tool "technology" and it is perhaps only that we have been using this tool indiscriminately. We should put this tool to use not only toward a comfortable life but also a healthy and a safe life for ourselves and for our future generations.

As a means to achieving this end, the concept of incorporation of environmental considerations at the initial stages of the planning process itself, is extremely important. This has not been considered necessary earlier. The adverse impact of several of our developmental projects on environment has brought this into sharp focus. The methodologies used and our experience in impact-assessment need to be refined. We must be aware that our expertise/experience in this area at present is in its infancy. This is an area where scientists from all disciplines should work together and pool their expertise, exchange views and data, and develop assessment-techniques suitable for various programmes. These can be adopted for immediate use with the ultimate objective of meeting our long-term requirements. This would prove to be a valuable tool and could be fruitfully utilized to foresee and forestall the negative effects of development. Environmental management should bring in its ambit not only pollution control, but also deforestation, extinction of flora and fauna, wildlife management, proper land use, soil conservation, afforestation, prevention of unplanned urbanization and industrialization, threat to our cultural heritage and indiscriminate use of natural resources.

The task before our scientists and technologists is stupendous. All our talent should be harnessed towards finding solutions and answers to these problems, keeping in mind that a better quality of life for our people is our ultimate objective. From the nature of problems facing us it is clear that environmental management does not or cannot limit itself to one or another area. It covers a wide-range of disciplines in science and humanities. This is evident from the topics chosen for discussion in several of the sectional areas.

I hope your deliberations will lead to a model where growth would be possible without the hazards that so many dread.

Scientists working in various scientific institutes should carry out applied research in resource management, in response to national needs. They should develop new methodologies for environmental analysis. There is a growing feeling even among scientists that environmental problems can best be solved through inter- and intra-scientific cooperation. Environment is the field where all disciplines will have to come together and resolve differences to save man's common heritage and lay down a base for sustainable development. This Congress should provide a common platform for grappling with national/global environmental problems and come out with certain fruitful conclusions.

I have pleasure in inaugurating this Congress. I do hope and believe that the results of this Congress will be of help to all researchers, industrialists, government and various scientific organizations in their efforts to make this country a better place to live in.

2

Environmental Priorities in India and Sustainable Development

T.N. Khoshoo

The focal theme of the seventy-third session is 'Science and Technology in Environmental Management'. One of its important facets is 'Environmental Priorities in India and Sustainable Development' which is the subject of this address. The 13 Sections as also two Committees and one Forum of the Indian Science Congress Association (ISCA) have taken up different aspects of the focal theme for their discussion. Taken as a whole, the seventy-third session is deliberating in a concert on the focal theme.

Environment has been defined as 'the sum total of all conditions and influences that affect the development and life of organisms'. This is a comprehensive definition as it stresses the totality of environment, and that every living organism, from the lowest to the highest, including the human being, has its own environment. The objective of the present address is to identify priority areas, and the way corrective action could lead to sustainability in development. This has to be done in relation to our particular social, cultural and economic milieu.

Historically we have been serious about the environment with the basic philosophy being one of *harmony* with nature as against the western concept of *conflict* with nature. We followed the latter during the last 150 years or so.

Since Independence, considerable progress has been made and today we are among the first ten industrialized nations of the world, thanks to the vision of the late Pandit Jawaharlal Nehru. Associated with any development, there is always some amount of environmental degradation. Since we did not have a culture of pollution control, we have with us today a huge backlog of 38 years (1947–85) of pollution and eco-degradation. While it is well known that Panditji was very keen on science, technology and industrial development, it will not be fair to him if we do not mention his concern for the environment. For instance, in 1957, when environment was not an important subject, he wrote: "we have many large scale river valley projects which are carefully worked out by engineers. I wonder, however, how much thought is given before the project is launched, to having an ecological survey of the area and to find out what the effect would be to the drainage system or to the flora and fauna of that area. It would be desirable to have such an ecological survey of these areas before the project is launched and thus avoid an imbalance of nature." One marvels at his sensitivity for maintaining environmental balance and one also marvels at the total lack of it at the bureaucratic/administrative level. If the latter had followed what Panditji had said, we would not have been in the present environmental mess. Even today, there are people who believe that there is more money in destroying environment than in conserving it. Tomorrow is not their concern.

Time has come when *sustainability in development has to enter in our planning process as one of the basic and permanent objectives.* However, sustainable development needs to be properly paraphrased. This address is aimed at provoking a thought process, discussion and a public debate on the subject, rather than talk about it with an air of finality.

Twelve areas have been identified where priority action is needed. In actual fact these would also constitute important steps towards sustainable development itself.

1) POPULATION STABILIZATION

Resources shrink as people multiply and demographic pressures lead to economic pressures. There have been a number of discussions on the subject; population, environment, natural resources and development are indeed interrelated. Age-wise, India is a very youthful country, with over 72 per cent people being children and youth. Such a situation is also very conducive to further population growth. By the year 2001, we are likely to have a population of between 959 and 1052 million. Can we afford this? When we account for about 15 per cent of the world population, with only 2.4 per cent of the world area available to us. The crux of the matter is that future population growth has to be related to the resource base. Our immediate task is to know the Carrying Capacity of our country. In any case, a zero population growth holds the key to our prosperity, and to achieve this the government must be prepared for a measure of unpopularity. This has to be accomplished in the next two decades or so. In turn, it takes us to the birth control strategies, education and vocation for women, which involve considerable scientific and technological inputs including biotechnology and immunology. A policy on population has to be enunciated not in isolation but in concert with a number of related ministries/departments.

2) INTEGRATED LAND USE PLANNING

Land is one of the important components of the life support system and has been overused and abused. In 1972, the late Shrimati Gandhi said about land, "We can no longer afford to neglect our most important natural resource. This is not simply an environmental problem but one which is basic to the future of our country." Ours is a predominantly agricultural country where land comes first. There are a number of competing demands on land, like agriculture, forestry, grasslands, urban and industrial (including mining) development, and transport. Our land statistics are indeed very confusing and therefore unreliable. For any meaningful planning we need a set of figures agreed upon by the concerned departments utilizing modern tools like the remote sensing. This is the first prerequisite. We also need a time-bound micro-level land use survey, starting with the village indicating our long-term requirements for competing land uses and land capability. Obviously, land use will have to be related to soil quality use, and not land economics. The total scenario of land use will need to be built up meticulously and backed by appropriate legislations, because the existing legislations are indeed very weak.

Connected with land use planning is Watershed Management, a problem of utmost urgency on account of the fact that our water regimes in the mountain ranges are threatened resulting in the depletion of water resources along with the attendant problems. Himalaya's water sheds are the most threatened in the world and need immediate attention. Wherever science-based reclamation work has been attempted, remarkable results have been achieved and high sediment loads have come down and protective, productive and economic benefits have accrued.

We need to evolve an environmentally sound Water Conservation and Management Policy at the earliest, otherwise the much needed increase in food production may not take place and, what is worse, rationing of drinking water may become the order of the day.

The river valley projects envisaged in future and those that are ongoing need to be looked into for their environmental impacts and due provision made for environmental safeguards. A basin-wise approach needs to be followed and the engineering component should be considered in conjunction with catchment and command areas development. The benefit-cost ratio of 1.5 fixed for dams needs to be suitably amended. Irrigation has been a mixed blessing. Unplanned irrigation has caused more problems and losses than solutions and gains. Irrigation has given maximum benefit under the low rainfall conditions. Degraded, mined and other type of wasteland should be reclaimed and put to some productive use. Mines and Minerals (Regulation and Development) Act (MMRD) 1957, needs to be suitably modified to bring in the environmental safe guards.

3) HEALTHY CROPLAND AND GRASSLAND

The country has performed exceedingly well in agriculture and production has increased from 50.8 million tonnes in 1950–51 to 155.5 million tonnes in 1984-85. It has to go up to 275 million tonnes in the year 2000 to feed a billion people. There is an urgent need to boost productivity per unit area per unit of time. A comparison of India and China, the two population giants, shows that China with 1.5 times more population is able to feed its people on 43 million ha less land because both production and productivity are nearly double that of India. The solution to our problem lies in closing the gap between actual and potential yields and thus growing vertically rather than horizontally in agriculture. Our agriculture would require another heavy infusion of genetics, especially genetic-engineering and cognate sciences. It is indeed gratifying that the Indian Council of Agricultural Research (ICAR), on its own, has taken to biotechnology. In course of time, it may be possible to release considerable land from the present agricultural holdings. In spite of the adverse environmental effects of high-input high-output agricultural technology, for the foreseeable future, the country will have to depend on this model, which cannot be suddenly changed in favour of environmentally sustainable but low input and relatively low output models like organic farming, no-till or minimum till agriculture.

The loss of top soil, quantity-wise, is the maximum in India, being 18.5 per cent of the total soil loss at the global level. Strategies to reduce the top soil loss need to be developed on an urgent basis.

The problem of grasslands and overgrazing has not received the deserved attention. It has been responsible for eco-degradation due to the fact that we have world's largest number of livestock which are very poor productivity-wise. A concerted effort needs to be made and a 13 point strategy is suggested in the text.

4) WOODLAND AND REVEGETATION

The effective forest cover today is perilously low being hardly 14 per cent, as revealed by remote sensing techniques. It should have been 33 per cent in the plains and 60 per cent in the hills. The causes are reasonably well known. Coupled with these is the widening gap between demand and supply of wood for diverse uses. The strategy to meet the shortages has to be chalked out against two major objectives of forestry: (a) affording long-term ecological security, and (b) supply of the goods and services to the people and industry through a well thought out plan of production. To achieve these objectives, three broad types of forestry, namely Conservation, Production, and Social Forestry need to be practiced.

Conservation forestry will cover natural vegetation in watersheds and fragile ecological areas and Biosphere Reserves, National Parks, etc., where no commercial exploitation can be allowed.

Production or Commercial or Industrial forestry aims at meeting the raw material demands of all forest-based industries. Here environmental imperatives and production need to be combined. As in agriculture, the power of science needs to be used in forestry, for increase in production and productivity. We have depended so far more or less only on the naturally occurring forestry stock. The time has come to domesticate tree crops as we have done in the case of food plants, and cattle. There is a need to assign this work to the Indian Council for Agricultural Research (ICAR) and agricultural universities who should treat it as tree-agriculture and apply principles of genetics, agronomy, plant protection and other inputs like biotechnology and tissue culture.

The third type of forestry is Social, Community or Agro-forestry. These have essentially similar or intergrading objectives, and have succeeded on non-government land. Basically this is a multipurpose forestry for food, timber, fuel and fodder to meet village needs that would relieve pressure on conservation forests. The programme is meant for the rural poor and is an ancient land use system where land is used for agriculture, forestry and animal husbandry either sequentially or simultaneously. Such an Agri-Silvi-Pastorial Model goes well with the predominantly rural setting of the country with over 576,000 villages dispersed over the whole country. One of the important advantage is that once people develop a stake, there is social fencing created for the protection of such forests. This model also goes very well with the essentially biomass-based society and economy of the country as a whole. There are a number of success stories at the micro-level in the country. The challenge lies in extending them to the macro-level by removing bottlenecks and constraints.

There is need for considerable inputs in forestry with regard to science and technology, education and training, and demonstration and extension, if it has to meet the foregoing objectives. Some of the important steps towards this have been spelt out in the main text. Future success will also depend on how well agriculture, forestry and animal husbandry, the three land-based vocations, can be integrated at the village level.

Forestry has been reduced to a game of numbers (number of saplings planted) often accompanied by a total mismatch between species planted, their end-use and the land-use. *It is this mismatch which, for instance, has turned social forestry as a "social forestry*" and given rise to the Eucalyptus Controversy. We have to realize that a mismatch between a food crop and land can cost us anything from six to 12 months, but a similar mistake in forestry will cost us one generation.

Some policy decisions, outlined in the body of the address, including the treating of forestry as a science and technology area, with need to be taken.

5) CONSERVATION OF BIOLOGICAL DIVERSITY

The biological wealth of the country is fairly considerable with nearly 45,000 plant and 65,000 animal species. However, our efforts at conservation have been directed mainly towards the conservation (more correctly preservation) of the big cats as also some large mammals, the crocodile and birds while we have altogether ignored plants, forest trees in particular, as also micro-organisms and mangroves and marine biological wealth. These are major lacunae in our efforts. Even in the case of big cats, the stress has been on the art of wildlife rather than the science of wildlife. In fact, we seem to have forgotten a simple biological principle that there is *no fixity of species*. A species arises, spreads and in course of time, it wanes due to biotypic depletion and/or changing environmental conditions. Therefore, conservation efforts have to be directed to keep the species from declining. Obviously, this cannot be achieved merely by fencing the area, but by a strategy based on principles of genetics and evolutionary biology.

It is also extremely important to base the conservation effort on an ecosystem basis and not on a species basis. On paper we have over 202 sanctuaries and 44 national parks but, in practice, we have no idea of the holdings in these areas. There has been considerable *adhocism* in declaring sanctuaries and national parks and some of these are hardly 0.04 sq km. Areawise all the sanctuaries and national parks have to be related to the minimum area demand of the species (animal and plant) that they are supposed to contain. The areas for which such an indepth exercise has been done by botanists, zoologists and foresters, are the proposed Biosphere Reserves. We know precisely what is aimed to be conserved. However, these areas have yet to be declared as Biosphere Reserves for one or the other reason. These are areas of vital importance to the country. For instance, the Silent Valley and the adjoining regions have contributed 20 major genes for disease and pest resistance in the case of rice. Similarly, India has contributed 152 economic plants whose centres of diversity are located in our country. While India, as also other tropical and subtropical countries, are rich in genes (origin and diversity), purposeful manipulation of these genes has been done by developed countries that are crop-rich. The protection of species and varieties that are gene-rich is therefore very important. In time to come, Protected Areas Management will become a major global enterprise with considerable money being spent on this venture. If we do not take action now, a gene-rich country such as ours, will be left behind even though we have the expertise and exerience that is second to none in this area.

Another aspect that needs to be looked into very urgently is the farming for fur from animals, frog legs, turtles, musk and high-value herbal drugs. These species have a use and in fact there already exists a cottage scale industry based on them. No amount of laws and policing can save these species because it affects socio-economically, the hereditary vocation of the rural communities. Production of these species alone will make collection of these species from wild uneconomical. Crash programmes aimed at domestication and production of these species is called for, because otherwise conservation for the sake of conservation cannot be 'sold' to the rural/tribal people.

There is a reasonable understanding of the threatened animals and plants, thanks to the work of Botanical and Zoological Surveys. However, it may be difficult to conserve each and every threatened species. A rationale for prioritization has been given in the body of the paper. Another way to conserve important species would be to assign a species of indigenous mammal, bird, tree and a flower to each state and monitor the programmes at the National level. An indicative list of 108 such species is given in Table 13 of the Presidential Address to the Indian Science Congress. At the central level, we could add *pipal* and lotus besides the tiger and the peacock. All the 112 species could be declared either national or state animals, birds, trees and flowers by Acts of Parliament and State Legislature. They would then get special protection.

6) CONTROL OF POLLUTION IN WATER AND AIR

All development is accompanied by some form of pollution and in our case, the major sources and domestic waste (both dispersed and point sources), thermal power, industry (in particular distilleries and hazardous chemicals), irrigation, auto-exhaust emissions and abuse of agricultural chemicals. Dispersed sources are also important because they affect both air and water. Domestic waste volume-wise constitutes up to 80 to 90 per cent of pollution, but on the basis of the Biochemical Oxygen Demand domestic pollution constitutes about 50 per cent and the remaining 50 per cent is from other sources.

The Department of Environment and Central and State Boards have been able to control pollution from about 50 per cent of the polluting industries during the last four years, an achievement which any country can justly be proud of. However, the backlog is gigantic and is accentuated by the indifference of other ministries/departments/public sector undertakings. Minimum National Standards (MINAS) with respect to some industries have been established. Implementation of MINAS would control pollution at source. The thermal power sector needs to be kept under a very close watch and timely action alone will prevent acidification of our atmosphere. If all units come up, we will have between 0.5 and 1 million tonnes of SO_2 being belched out in the air, and apart from NO_x, suspended particulate matter and a huge quantity of ash. In the name of power generation, the country may pay much more by way of social costs, health budgets, and loss of productivity.

Bhopal should be a constant reminder of how fragile our industrial safety system is and much is to be learnt from this unfortunate incident.

Water pollution needs to be controlled river-basin-wise, like the Ganga

Action Plan. However, the present strategy in Ganga deals with bricks, mortar and drainpipes. All our rivers are to be looked at as resources. We need to take a total approach including 'Solution to Pollution by Dilution'. In this connection, there is a valuable contribution by Rama in as early as 1971, supported by Roger Revelle (personal communication). The rationale is holistic and details are given in the body of this address.

Essentially pollution control can be achieved by laying down realistic minimum standards, proper legal back up and creation of a strong research and development base to monitor and to act as Early Warning System.

7) DEVELOPMENT OF NON-POLLUTING RENEWABLE ENERGY SYSTEMS

Energy is a very important input for development. In fact, there is a correlation between level of development and amount of energy used by a country. The non-renewable forms of energy are regarded as energy capital and wisdom lies in not expending the capital. The energy crisis has shown that sustainability in the energy sector can be brought about by conserving the non-renewable sources as also by replacing/supplementing them by non-polluting renewable ones, which are more or less pollution-free, environmentally clean, renewable and socially relevant. Most of the non-renewable sources are highly polluting. Furthermore, no nation can now afford to depend on only one form of energy. It shall have to be a mix of at least seven forms (biomass, solar, coal, petroleum, natural gas, hydro and nuclear), each supplying not more than 20 per cent of the total energy needs of a nation. These should be backed by foolproof environmental safeguards. Furthermore, the relevance of renewable form of energy, particularly biomass, can not be questioned in a country like India where there are over 5,76,000 villages. Firewood is still a very important source of cooking and heating in the rural and the urban-poor setting. The demand is likely to treble by the turn of the century. The firewood crisis can be solved only by a crash programme of production of firewood. Furthermore, the nexus between fuel and food and fodder has to be appreciated in a village system. This alone would lead to a decentralized and a local system, because electrifying every village home is still a far cry.

Biogas is another major source for meeting the energy crisis in rural areas provided feedstock supply is diversified and is ensured. Other sources are micro-hydel, solar, wind, ocean and geothermal.

There is need for a good measure of research and development input in all forms of non-conventional sources of energy and periodic monitoring of performance of these systems.

A perspective in the energy scene is yet to be developed. In the immediate future, the country will have to conserve to the maximum extent, the commercial sources on the one hand, and replace and supplement the same with non-conventional sources on the other.

8) RECYCLING OF WASTES AND RESIDUES

In order to maintain stable economic growth in future, it is necessary that resources are used carefully and technologies for recycling wastes and residues are evolved. Besides saving energy, resources are a trust to be held for future generations. There is a global realization that a nation that will not be able to recycle materials, will not be able to sustain itself because single or one-time use will lead to scarcity.

Several developed countries notably Japan and to some extent, Holland, Great Britain, West Germany, Denmark and the U.S.A. are working very actively in the area of recycling and even re-use. Recycling and re-use have been a way of life in China. Both traditional and updated methods are followed to use practically all bio-materials available at the village level. These have considerable social, economic and environmental advantages.

The extent and nature of wastes available in India was assessed by National Committee on Science and Technology (NCST) in 1975. This is an excellent report which may need some updating. The NCST group has made some important recommendations which need to be looked into for implementation. Time will soon come when scavenging will become a big business, and in coming decades, the country has to concentrate on the utilization of all types of wastes.

9) ECOLOGICALLY COMPATIBLE HUMAN SETTLEMENTS AND SLUM IMPROVEMENT

Negative impacts of the absence of housing are indeed a cause of a lot of human misery with consequent degradation of physical health, economic, social and cultural environment in urban, slum and in rural areas. Due to doubling of population from 1951 to 1981, there has been a 300 per cent increase in the number of persons per sq km. At present, there is shortage of at least 21 million houses, 16 million (76 per cent) in rural areas and 5 million (24 per cent) in urban areas. The population in slums is likely to go up from 28 million to 55.2 million by 1990. Commensurate with this is ill-planned or unplanned or even absence of water supply and sanitation systems. Furthermore, in any programme on drinking water, sewerage has been constantly ignored. The refuse, therefore, affects water bodies and in turn causes problems of environmental sanitation and health as 80 per cent of the diseases are water-related. The vulnerable sections of our society, and among them women and children, suffer the most.

While gas leaks make headline news, even larger number of people die unknown, unheard and unwept due to bad environmental sanitation. How many geniuses we lose everyday is not known. This is the result of a strong urban bias. Furthermore, there has been a tendency to accuse the rural and slum dwellers for environmental degradation, but it is actually the urban high-energy and high-consumptive life styles which, in the ultimate analysis, put pressure on the rural system. If we are serious about improving the living conditions of the weaker sections of our society, it is important that the lifestyles of urban people become less energy demanding and less consumptive. Upgraded slums will continue to be slums as long as there is no socio-economic upliftment.

There is also an immediate need for research and development with regard to utilization of traditional, locally available building materials, and architecture in relation to local ecology, low cost latrines using minimum water and parameters for environmentally compatible human settlements. Regarding the last item, a list of prerequisites has been given in the body of this address.

10) ENVIRONMENTAL EDUCATION AND AWARENESS

Today one of the major priorities of the central government is education. In fact with the acceptance of the Tiwari Committee Report (Department of Science and Technology, 1980), the country has accepted the need for environmental education. The basic rationale is that the people themselves are a renewable resource and we need to train them to help restore our environment. Many conferences, national and international, have been held, but the fact remains that while most people recognize the urgent need for environmental education, only some have clear ideas about what needs to be done, and very few have either the actual experience or the knowledge of the courses that need to be taught. The attempt should not be to introduce a new subject, but a *new approach* to environmental education which cuts across various subjects. The idea should be to bring environmental concerns in all subject areas so that environmental bias permeates into all facets of one's life and does not get compartmentalized at one place.

The basic rationale of designing courses in the formal education sector at school, college and university has been spelt out in the text of this address.

The non-formal sector must cater to adult education, rural youth and non-student youth, tribals and forest dwellers, children, public representatives, senior executives and administrators, and foundation courses for probationary officers from various services including the armed forces, and trained manpower (teachers, professionals, technicians and legal experts).

11) UPDATING ENVIRONMENTAL LAW

While there is a plethora of central and state laws/enactments which have direct or indirect relevance to environment, none, except perhaps Water and Air Acts, take care of the short and the long range effects on environment. For instance, a number of laws may be related to hazardous chemicals but none take into account the basic fact these chemicals can enter the life support system and the food chain and ultimately affect human beings. The basic question whether environment should figure in the Union or Concurrent List also needs to be looked into. There is an urgent need to update the existing laws; in fact this has to be a regular activity so that laws are able to meet the newer environmental challenges and insulate the country from future environmental damage. An indicative list has been given in the body of the address. Environmental law is not law alone, it is law in combination with scientific and technical data without which neither effective laws can be formulated nor cases decided objectively so as to ensure sustainability in development.

Today, there is a growing awareness all over the world that all living beings have a standing and an intrinsic value, an opinion expressed some 3,000 years ago by Charka in India. Therefore, all living things, plants and animals, have a right to live. This goes well with our own conservation ethic.

12) NEW DIMENSIONS TO NATIONAL SECURITY

The prevailing concept of national security is confined to the defence preparedness to meet threats from within and, more important, across the borders. Defence all over the world is the largest budget head of most nations. This concept has been widened by talking of food security which envisages 'physical and economic access to food to all people at all times'. Food security has been further refined to include Nutritional Security. However, we have always ignored a bigger security, the long range environmental security, which is a non-military threat. We are waging a war against our life support systems and seem to be winning it. This realization is dawning on our hill people and an ex-serviceman has said: "I was in the West Bengal Rifles for 27 years and I fought three wars. I have now returned to my village. My enemy is no longer Pakistan or China: it is land slides. We live in fear of land slides. We need trees to give us healthy environment so that we can survive." This is the prevailing opinion in the entire Himalayan Belt, where people have become aware of the dangers to their very existence and demand curative action. The future of 400 million people in low lands of Pakistan, India and Bangladesh, depends on the wellbeing of the Himalaya and its 46 million people in Pakistan, India, Nepal, Bhutan and Burma. For instance, what happens in the Nepal Himalaya must inevitably affect us in the Indian plains. Here then is a very important item for bilateral cooperation as also for regional cooperation between the countries in the entire Himalayan Belt for the good of their people. History is replete with instances where civilizations have fallen just because the countries concerned did not take care of the environmental base. Therefore, we need to mount a full scale assault through science-based programmes so as to ensure our national security. Environment transcends geographic boundaries and merits attention with minimum political differences and inevitably must enter the area of foreign relations.

General Considerations

The words *economics* and *ecology* have the same root, *oikos*, which refers to *house*. While economics deals with financial housekeeping, ecology deals with environmental housekeeping. Time has come to see that economic planning and environmental protection have identical goals of sustainable development which, therefore, must be deeply integrated in the planning process. Sustainable development is necessary on a long-term basis, and, in common parlance, would mean spending the interest while keeping the capital intact.

I have spoken marginally about non-renewable resources, but the concept of sustainability will apply to these resources much more than the renewable ones. The present generation has to think about what it owes to the ones that will follow. How much coal, petroleum and minerals do we have and what is the pattern we should follow to make them last longer. This has to be coupled with a major programme on recycling and re-use.

The option before us is either a Throw-away and One-way Society or a Sustainable and Earthmanship Society. The current Throwaway or One-way Society can become sustainable only if there is an infinite supply of materials and energy. It pre-supposes that the environment has equally infinite ability for absorption and resilience to return to its original condition, after unlimited quantities of waste and heat are generated. Experience has shown that this is no longer tenable particularly on account of the escalating population and shrinking resource base. The other model is Sustainable or Earthmanship Society aimed at recycling and re-using materials, conserving energy, controlling population and pollution, and lowering the rate of consumption of materials (including forests) and energy by deliberate choice, so that resources are not depleted and the environment does not deteriorate due to overloading with wastes and loss of vegetal cover. This model goes well with our conservation ethic. The choice, therefore, is clear.

It is time we stop confining ourselves only to what may be called reactive-environmentalism and moved on to long-range environmentalism. Reacting to the local environmental issues is only 'skirting the basic issues'. One such basic issue discussed below relates to the model of development itself that we should follow for the unusually large number of villages we have. This is why Gandhiji aptly said that India is in villages "If villages perish, India perishes". It is indeed a far cry that through central grids, we can meet the minimum basic needs of all the villages. Centralized planning has failed to percolate fully to the grassroots. Essentially, the village society and economy is biomass-based and for amelioration of the condition of the rural poor there is need to enhance the productivity of biomass on a holistic basis. The ecosystems need to be built up, nursed and cared for. While discussing cropland, woodland and grassland, the three land-based activities, and their nexus with rural energy, it emerged that we need an Agri-Silvi-Pastoral Model of development. This alone will lead to self-sufficiency at the rural level while keeping the environment clean and forging sustainable development.

Between the Industrial Development Model and the Biomass-based Model, a perceptible tilt should be made in favour of the latter, which essentially is based on photosynthesis. This goes well with the fact that Indians are, by and large, vegetarian and there is an in-built veneration for all life. Among other things, the model envisages revegetating the uncultivated half of India and making the country verdant. This would have distinct environmental, social and economic benefits and will help in the following ways:

—Conservation and improvement of soil and water
—Stabilization of catchments and watersheds
—Control of floods
—Better microclimate
—Creation of aesthetic and pleasing landscapes
—Better health
—Better quality of life
—Halting the influx of rural population into urban areas and
—Decentralized economy.

One way to achieve this on a priority basis under the National Rural Employment Programme (NREP), Employment Guarantee Scheme (EGS) and several other related programmes, is to ensure massive public participation, involving students, volunteers, exservicemen and the public at large, for the success of a massive field project like the restoration of degraded land and ecosystems. In fact, the people can be organised at the national, state or local level into Conservation and Development Corps (CDC). The programme would instil in the young people a work ethic and sense of pride. The underlying philosophy is to make villages self-sufficient with regard to food, fodder, fuel and timber by producing or raising those materials that are in demand at the village level. Meaningful results have been achieved in a short time wherever this model has been given a fair trial.

Four important issues of a policy nature have emerged from the actual work and working at the centre and in the states as also discussion of environmental issues in this address. These are:

1) The plans for environmental management should be integrated in all the developmental activities of all sectorial authorities (from a ministry/department/development agency/corporate body/municipal council down to the *panchayat*) who have the primary responsibility for environmental protection. Implicit in this statement are the following points:

—A mass education and awareness programme from primary school children to professionals, policy and decision makers and everyone in between.
—The Departments of Environment at the centre and in the states have to perform a 'watch dog' role and *clubbing them with other departments would be counter productive.*
—Key to the success in environment lies in cooperation between central and state governments.

—Environmental management (including Impact Assessment) should be a statutory obligation for all developmental projects.

—For sustainability of high productivity, resources have to be made available for all times to come. It is only possible if we manage them well.

2) Programmes on environmental amelioration can succeed only when participation of public is secured and ensured and public at large develop a stake in environment.

3) A strong science and technology base is needed for environmental research and development, education and training and demonstration and extension. This is an essential pre-requisite for any meaningful progress in this area. An equally important area of work is the social cost benefit; in other words, at whose cost and to whose benefit.

4) Mechanisms need to be strengthened for ensuring:

—Corrective or curative or restorative action with regard to environmental damage that has already taken place. An example of such action is Mission on Ganga.

—Preemptive action needs to be taken regarding the environmental damage expected from the future developmental activities and thereby insulating the country from further damage. An example of this is the stoppage of the Silent Valley Hydroelectric Project in favour of the role this area has as a repository of biological diversity.

Suggested Recommendations

The principles of environmental management will have to be applied to all developmental activities. Inherently, environmental management is inter-disciplinary and inter-departmental/ministerial in character. Furthermore, in our country, land, water and forests are state subjects which means a very high degree of interface between the central and the state Governments. There is, therefore, an urgent need for a national body, outside the Department of Environment, to advise the government on pressing national environmental issues. Such a role was apportioned by the previous government to the Scientific Advisory Committee to the Cabinet and some excellent work was done on forestry and hazardous substances by the previous SACC. The same arrangement can continue, or this work can be assigned to a small tight body of two to three persons, like the Council of Environmental Quality (CEQ) advising the President of the U.S.A. CEQ was in the President's Office, outside the jurisdiction of the Environmental Protection Agency (EPA), which is the counterpart body of the Department of Environment and the Central Board in India. With this in mind, the following recommendations are suggested:

1) The most urgent and pressing problem is the preparation of the National Conservation Strategy (NCS), not only involving governmental but more

importantly also non-governmental organizations. In fact, NCS would lead to a National Environmental Policy. However, before it can be accomplished there would be needed clear statements on population policy, interface between population, land, food and other resources, carrying capacity, integrated land use management, land use classes, land capability survey and land use policy, water conservation and management policy, and other cognate issues regarding river valley projects, dams and irrigation, mining, policy on recycling and re-use, policy on hazardous substances, etc. All these issues can no longer be brushed aside and have to be dealt with scientifically on an urgent basis.

Such a supra departmental body could also prepare an environmental perspective on issues of national, regional and global importance.

2) The recommendation of the Tiwari Committee about appointing well-trained and well-informed Environmental Advisers in all the ministries needs to be activized at the earliest.

3) A policy research and training institute on the management of environment needs to be established to look after the training needs for Environmental Advisers as also take up work on some of the policy issues outlined above.

4) Special attention needs to be paid to the rehabilitation of the Himalaya and work on the Himalayan Institute on Environment and Development needs to be expedited as a Network Institute. The government has already decided to name the Institute after the late Shrimati Indira Gandhi. Work needs to be intensified on this project, not only nationally but also regionally.

This address is rather long. The reason being, a constant clamour for authentic information from teaching, training and research institution. The information is very dispersed and not readily available. I have tried to put it between two covers in the hope that it will prove to be useful.

So far, the nations of the world did not have a common past, but are now moving towards a common future through the area of environment on which depends the very existence of the human race. The thoughts expressed in this address are dedicated to the memory of a great leader of our time, the late Shrimati Indira Gandhi. Posterity will always remember her for the thrust she gave to the environmental movement both in India and at the global level. May her memories guide us to right action in the area of environment.

Let me end where I began. Environment is a truely multi-disciplinary area and all of us are in a learning phase. We need collective wisdom from various disciplines to solve environmental problems which are often very complex. Let us recapitulate the aphorism from the *Rigveda*:

aa no badra kratavo
yantu vishvataha

"Let knowledge and noble thoughts come to us from all sides."

II

MATHEMATICAL SCIENCES

3

Perspectives on Applied Mathematical Modelling with Special Reference to Atmospheric-Oceanic and Physiological Sciences

M.P. Singh

This paper discusses a topic which has been engaging the attention of Applied Mathematicians of the country for a long time—the application of mathematics in real life problems relevant to the needs of the country.

Most of the world's mathematicians have been worshipping mathematics in two forms, one perfect but of no use and the other imperfect but highly serviceable. To the former class mathematics is the beautiful queen of sciences, commanding adoration and appreciation but of no utility except to satisfy the emotional needs of her subject. To the latter class of mathematicians, the subject is an efficient tool, a reliable friend, a dependable servant who helps them to resolve the complex problems affecting the day to day life of human beings. I would like to address the former class of mathematicians that although in its own ivory tower mathematics is beautiful, perfect, its image gets blurred in the rough and tumble of actualities, but what is lost in beauty is gained in utility, for a civilization without mathematics is inconceivable.

Background

It has been felt for a long time that research in mathematics in the country lacks relevance. Although the country has a large body of active researchers in mathematics, the resources have not been fully tapped to solve some of the relevant problems in priority areas as identified in the Science and Technology plan. This seems to be an opportune time to orient the research interests of the faculty and researchers of various universities and institutions to tackle some of the relevant problems of national importance in the areas of priority like Atmospheric Sciences, Oceanic Sciences, Environmental Sciences, Social Sciences, other branches of fluid dynamics like MHD and Astrophysics.

In this context, I would like to mention the work being done at IIT Delhi, where a Centre for Advanced Studies in Atmospheric and Fluid Sciences has been set up by the Ministry of Education under the Sixth Five Year Plan. This Centre is giving special emphasis to mathematical modelling in Atmospheric Sciences, Oceanic Sciences and Physiological Fluid Dynamics. The scientists of this Centre have made significant progress in these fields. Given briefly are some of the highlights of the scientific achievements of the Centre.

Highlights of Scientific Achievements at the IIT Delhi

The Centre for Advanced Studies in Atmospheric and Fluid Sciences has taken up the following four major thrust areas for development:

1) Monsoon Studies
2) Storm Surge Prediction
3) Air Pollution Modelling
4) Physiological Cardio Vascular Fluid Dynamics.

1) MONSOON STUDIES

a) Introduction

It is well-known that the annual food production and hydroelectric power generation in the country lean heavily on monsoon rainfall. It has rightly been mentioned that the Indian Budget is a monsoon gamble. Advance information is urgently needed on three aspects of the monsoon: (i) the likely dates of onset and withdrawal of the monsoon, (ii) periods of heavy and defficient rainfall during the monsoon season (June 1-September 30), and (iii) the total quantum of monsoon rainfall. Monsoon modelling is, therefore, one of the prime objectives of continued research in India, and accordingly this has been the main topic of investigation by the scientists of the Centre. To accomplish this objective, efforts were mainly directed towards the development of a General Circulation Model with a capability of medium-range weather forecasting and for undertaking climate variability studies.

As a result of five years continued efforts, the Centre succeeded in the development of a variable grid General Circulation Model which is unique of its kind and has been termed as the Monsoon General Circulation Model (MGCM). The unique feature of the model is that it allows higher concentrations of grid points in the Indian monsoon area and thus allows a finer description of the monsoon structure while retaining the main features of the global general circulation. The formulation of the model and its performance in the simulation of Indian Summer Monsoon is described here.

b) *Formulation of the model*

The model equations are governed by the well known laws of conservation of momentum, mass and energy. This model is written in σ-coordinate (pressure normalized by surface pressure, p/p_s) which has the advantage of incorporating the lower boundary condition in an easier way as the earth's surface becomes the coordinate surface. In the horizontal the resolution is variable which gives finer resolution over the monsoon area (Fig. 1).

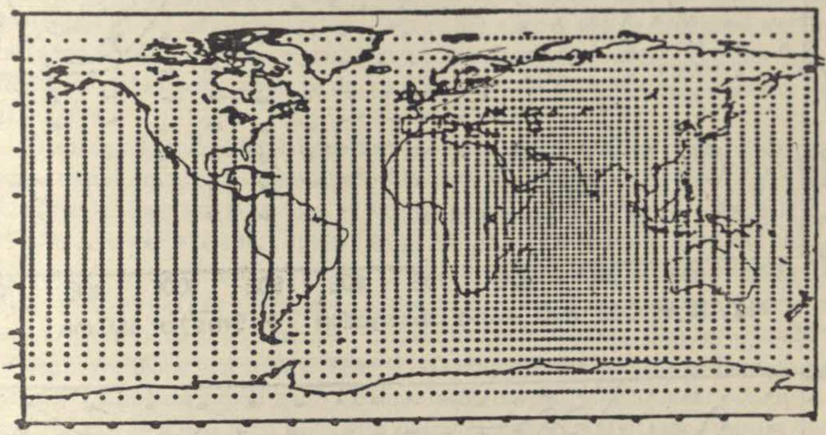
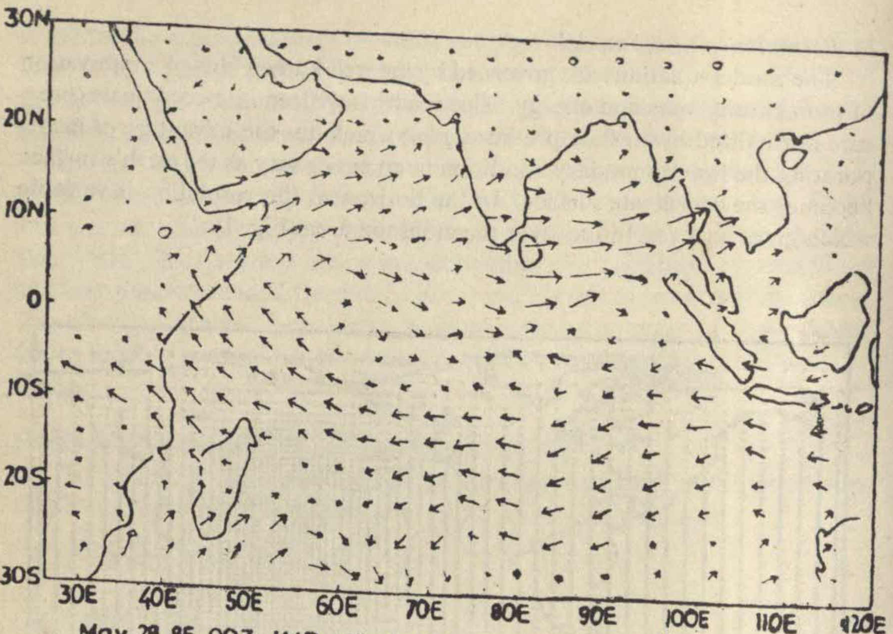


Fig. 1. The monsoon general circulation model showing finer grid size over the monsoon region.

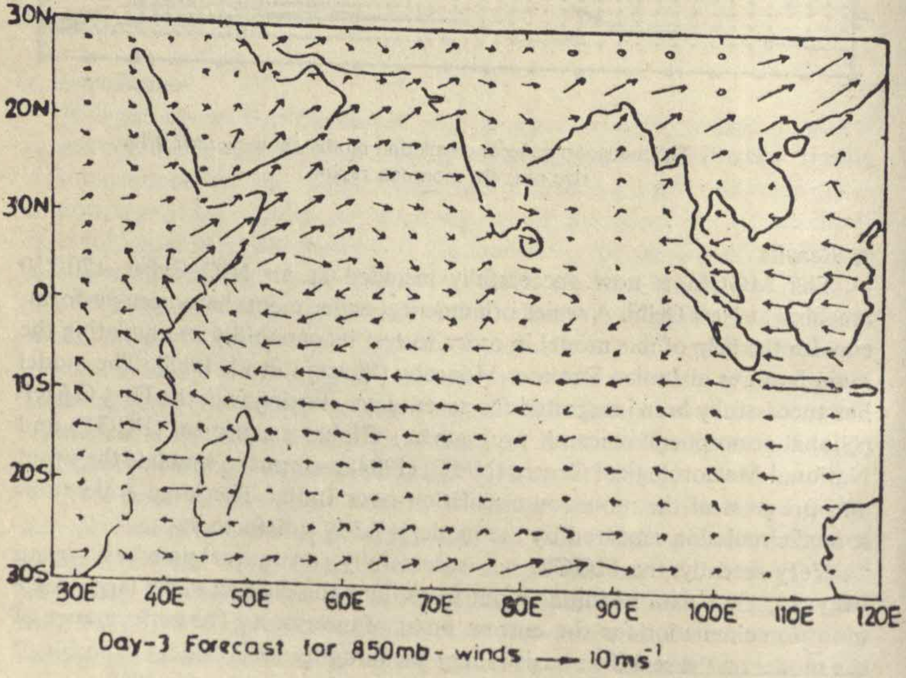
c) *Results*

The MGCM is now successfully installed at an NIC Cyber 170/730 machine at New Delhi. A series of numerical experiments have been performed with the help of this model in order to test its capability in simulating the main features of Indian Summer Monsoon (Sharma et al. 1985). The model has successfully been integrated for seven days starting with the First GARP (Global atmospheric research programme) Global experiment (FGGE) and National Meteorological Centre (NMC) (1984) as input to simulate the onset and progress of the monsoon circulation over India. The large scale monsoonal circulation captured by the model is fairly satisfactory.

Very recently, the MGCM was successfully run on real time basis using May 25, 1985 data as initial input to capture the characteristic large scale monsoon circulation for the current onset of monsoon. The performance of the model on the real time basis is very encouraging as is evident from Fig. 2 which shows the predicted and observed circulation on May 28, 1985.



May 28, 85 00Z IMD Wind observation (→ 5 ms^{-1}) at 850 mb



Day-3 Forecast for 850mb- winds → 10 ms^{-1}

Fig. 2. Observed and predicted (by MGCM) wind circulation for May 28, 1985.

2) STORM SURGE PREDICTION

a) *Introduction*

Storm surges are the outcome of cyclonic winds blowing over a large surface of water, which is bounded by a shallow basin. The driving force of winds leads to accumulation of water on the shoreline which, in turn, results in a sudden and substantial rise in sea level. The tropical storms and associated surges are of very common occurrence along our coastal areas. These systems directly affect the life and property of the habitants which is a heavy burden on our exchequer. There can be little doubt that the number of casualties would be considerably lower if the surges can be predicted well in advance to allow effective warnings in the threatened areas. Considerable importance has been given to the problem by the scientists of the centre at IIT Delhi.

Numerical models have been developed for the prediction of storm surges and coastal inundation associated with severe cyclones in the Bay of Bengal and the Arabian Sea (Das et al., 1983; Dube et al., 1981a, 1981b, 1984, 1985a, 1985b; Johns et al., 1981, 1982, 1983a, 1983b, 1985; Sinha et al., 1984 etc.). The noteworthy difference in the formulation of these models, from those developed earlier for the region, is the way in which the topography of the east coast of India is represented. These models for the first time, are capable of dealing with curved coasts. The "IIT-D Numerical Storm Surge Prediction Model" is now installed at the India Meteorological Department computer for trial run on a real time basis with a view to test its performance during the next two years.

b) *Formulation of the model*

The basic hydrodynamic equations of continuity and momentum for the dynamical process in the sea form the basis of the formulation of the numerical model. The vertically integrated form of these equations are given by

$$\frac{\partial \xi}{\partial t}+\frac{\partial \tilde{u}}{\partial x}+\frac{\partial \tilde{v}}{\partial y}=0$$

$$\frac{\partial \tilde{u}}{\partial t}+\frac{\partial}{\partial x}(u\tilde{u})+\frac{\partial}{\partial y}(v\tilde{u})-f\tilde{v}=-g\,(\xi+h)\,\frac{\partial \xi}{\partial x}-\frac{1}{\rho}(\xi+h)\frac{\partial p_a}{\partial x}$$

$$+\frac{Fs}{\rho}-\frac{C_f\tilde{u}}{(\xi+h)}(u^2+v^2)^{1/2} \quad \text{and}$$

$$\frac{\partial \tilde{v}}{\partial t}+\frac{\partial}{\partial x}(u\tilde{v})+\frac{\partial}{\partial y}(v\tilde{v})+f\tilde{u}=-g\,(\xi+h)\,\frac{\partial \xi}{\partial y}-\frac{1}{\rho}\,(\xi+h)\,\frac{\partial p_a}{\partial y}+\frac{G_s}{\rho}$$

$$-\frac{C_f\tilde{v}}{(\xi+h)}(u^2+v^2)^{1/2}$$

where

u, v: depth averaged components of the directions of x and y respectively,
p_a: the atmospheric pressure,
ξ: sea-surface elevation,
$(\tilde{u}, \tilde{v})$: $[(\xi+h)\,u, (\xi+h)\,v]$ are new prognostic variables,
$(\xi+h)$: total depth of the basin,
(F_s, G_s): Wind stress components,
C_f: 2.6×10^{-2}, an empirical bottom friction coefficient,
ρ: Density of the sea-water.

The above predictive equations are solved numerically subject to following initial and boundary conditions:

$\xi=u=v=0$ everywhere for $t\leqslant 0$

At the coast, transport must vanish, i.e. $u\cos\alpha+v\sin\alpha=0$ for all $t\geqslant 0$, where α denotes the inclination of the outward drawn normal to the x-axis.

Normal currents across the open sea boundaries may be prescribed by a radiation type of condition.

c) *Results*

The model has been used successfully in simulating the surges generated by the devastating 1970 Chittagong, 1975 Porbandar, 1977 Andhra and 1982 Orissa and Saurashtra cyclones. The model results are very encouraging and indicate that they can be used for predicting the surge generated by the cyclone of any speed and intensity.

Figure 3 gives the distribution of the predicted maximum sea-surface elevation (———) predicted time of occurrence (- – – –), observed surge (*) and its time of occurrence (0) along the north Orissa coast during June 1982 cyclone. It may be seen from the figure that the model predicted maximum surge is in fairly good agreement with the observed surge at two tidal stations, Paradip and Dharma.

3) AIR POLLUTION MODELLINGS

a) *Introduction*

There has been increasing realization that measures must be taken to protect air quality in the face of rapid industrialization and urbanization. Sulphur dioxide (SO_2) and carbon monoxide (CO) are the two major pollutants which are found in the urban areas. These pollutants directly affect human beings, plants, monuments and industrial structures. As a consequence, there is an urgent need to protect and preserve the air quality. It is not always possible to measure concentration of toxic gases and pollutants at vulnerable points of a city or industrial complex, but much insight in this connection could be

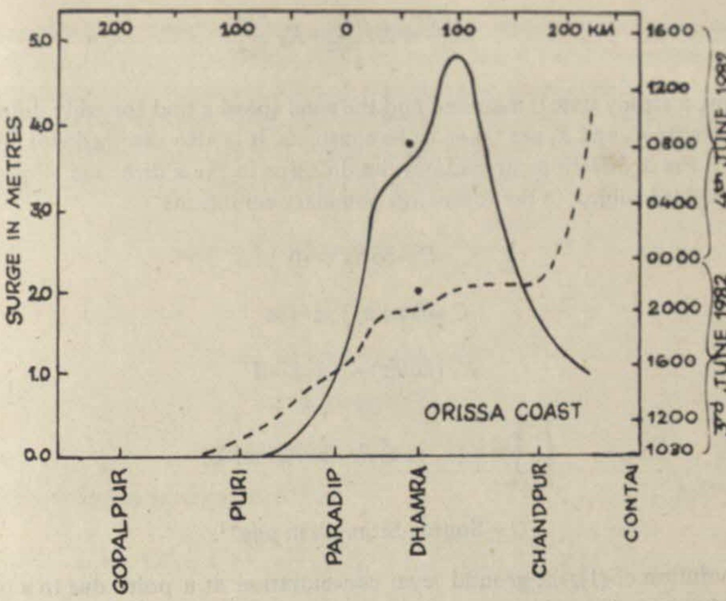


Fig. 3. Distribution of the predicted maximum sea-surface elevation (———), predicted time of occurrence (- - - -), observed surge (*) and its time of occurrence (o) along the north Orissa coast during June 1982 cyclone.

obtained through validated models which can predict the pollutant concentrations due to various sources.

Mathematical models have been developed by the scientists of the Centre which are capable of predicting the major pollutants, SO_2 (long-term prediction), and CO (short-term prediction) in the city of Agra and Delhi respectively.

Since vehicular traffic has been identified as the major anthropogenic source for CO, a detailed 'source inventory' is developed for the city of Delhi based on total CO emission and the traffic pattern around the city (Raghavan and Murty, 1985; Raghavan et al., 1986).

Domestic coal burning is a common feature for the city of Agra which has been identified as one of the major sources for SO_2 emissions. A source inventory has been developed for the same based on the domestic consumption of coal (Raghavan et al., 1983).

b) *Formulation of the model*

The model is based on a relatively simple Gaussian plume approach, but is 'receptor oriented' that is the ground level concentrations at a receptor due to contributions from all the sources lying within the angular segments through an arc of 22.5° upwind of the receptor point are summed. The basic diffusion equation used in the model is

$$u\frac{\partial c}{\partial x}=K_y\frac{\partial^2 c}{\partial y^2}+K_z\frac{\partial^2 c}{\partial z^2} \tag{1}$$

In this, a steady state is assumed and the wind speed u and the eddy diffusion coefficients K_y and K_z are taken to be constants. It is also assumed that advection in the x direction outshadows the diffusion in the x direction. Equation (1) is solved subject to the following boundary conditions

$$C\rightarrow\infty \text{ as } x\rightarrow 0$$

$$C\rightarrow 0 \text{ as } x, y, z\rightarrow\infty$$

$$K_z\ (\partial c/\partial z)\rightarrow 0 \text{ as } z\rightarrow 0$$

$$\int_0^{\infty}\int_{-\infty}^{\infty} u\, c\, (x, y, z)\, dy\, dz=Q,\ x>0;$$

$$Q=\text{Source Strength in } \mu g s^{-1}.$$

The solution of (1), the ground level concentration at a point due to a point source at ground level is

$$C=\frac{Q}{\Pi_{\sigma y\ \sigma z}\, u}\, e^{-(y^2/2\sigma y^2)} \tag{2}$$

here, $\sigma_y=\sqrt{2K_y\, x/u};\ \sigma_z=\sqrt{2K_z\, x/u}$

for area sources (2) is integrated to give C as

$$C=\int_0^{\infty}\int_{-\infty}^{\infty} Q e^{(-y^2/2\sigma y^2)\, dy\, dx} \tag{3}$$

Gifford's (1959), narrow plume hypothesis permits the elimination of the y dependence in (3).

Thus integrating with respect to y

$$C=\sqrt{\left(\frac{2}{\pi}\right)}\int_0^{\infty}\frac{Q}{u\sigma_z}\, dx \tag{4}$$

$$\sigma_z=ax^b$$

a, b are the stability parameters. (4) is integrated piece-wise for obtaining C. For short-term (hourly) concentrations, C is calculated at each receptor according to the hourly wind and stability. For long-term (six-monthly mean) concentrations, C at any receptor can be derived from the model by successive applications of (4) to 16 wind directions and weighting it with the appropriate combination of the frequency of wind, stability and speed class.

Under convective situations, the emperical relationship of vertical spread (σ_z) is not appropriate. Hence a modified version of σ_z (Briggs, 1984) under convective conditions is used for the CO model given by

$$\sigma_z/z_i = X\left[0.6\,X + \left[0.64\,\frac{u_*}{w_*}\right]^2\right]^{1/2} \tag{5}$$

$$X = (w^*/u)\,x/z_i$$

u_* = frictional velocity

z_i = mixing height

w_* = convective velocity scale.

The concentration is calculated from

$$C = \sqrt{(2/\pi)}\;1/u\left[\frac{Q}{\sqrt{(A)}}\,ln\left(\frac{\sqrt{(A+Bx)}-\sqrt{(A)}}{\sqrt{(A+Bx)}+\sqrt{(A)}}\right)\right]_0^\infty \tag{6}$$

$$A = \left(\cdot 64\,\frac{u_*}{u}\right)^2 ;\; B = \cdot 6\left(\frac{w_*}{uz_i}\right)^3 z_i^2$$

c) *Results*

The model is capable of predicting the annual mean concentration of SO_2 for the city of Agra quite well. Predicted concentrations of SO_2 at five stations are compared against observations which are quite satisfactory as shown in Table 1 (Raghavan et al., 1983). The results conclude that any strategy for reducing SO_2 emissions should consider domestic use of coal.

TABLE 1

Showing the projection of SO_2 levels in Agra in 1991 due to domestic sources (units: $\mu g/m^3$).

Name of station	Concentration due to all sources in 1975–76 (half-yearly mean)		Concentration due to domestic sources in 1975–76	Concentration due to domestic source in 1991
	Predicted	*Observed*		
Taj Mahal	21.3	20.0	11.3	15.7
Agra Fort	36.4	34.5	24.7	34.5
Itmaduddaulah	31.9	28.3	19.7	27.6
Nagar Mahapalica	23.3	16.3	19.5	27.3
Sikandra	6.8	9.8	5.4	7.6

Observations of hourly CO concentrations were available at ITO for a few days in January, February and March 1983. A comparison of the model results with the observations are shown in Fig. 4, for a particular day (5th Feb., 1983). The results are quite encouraging. A comparison of model results with more observations at other stations could enable us to use the model for taking preventive measures in the near future.

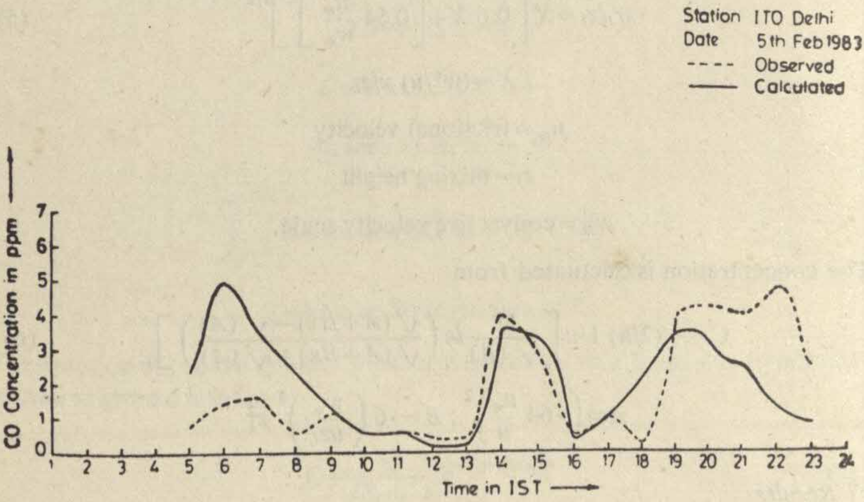


Fig. 4. Observed (– – – –) and calculated (———) values of hourly CO concentrations near ITO, Delhi, for February 5, 1983.

4) Cardiovascular Fluid Dynamics

a) *Introduction*

The research on cardiovascular flows is motivated by the desire to understand the origin and progression of the arterial disease, arteriosclerosis. The disease, which is believed to be due to the deposition of fatty particles on the arterial wall, is found in some preferential sites. This suggests that fluid dynamics of the blood flow may be responsible for these preferred sites. As the deposition continues, the arteriosclerotic plaques lead to a constriction, known as stenosis, which alters the blood flow. The resistance offered to the flow in such a situation would provide vital information in understanding the progression of the disease. It is necessary to find the influence of blood flow and its pulsatile characteristics on the transport of blood elements between the blood and the arterial wall.

Another important cause of the disease is the transport of macromolecules like lipoproteins across the arterial wall from the blood stream. This transport is considered to be the cause of intimal thickening.

b) Mathematical formulation

The transport of the macromolecules across the arterial wall is studied by modelling the artery as a composite of a porous elastic matrix and fluid passing through the pores. The system of equations is constituted by the equation of equilibrium, Darey's law and the continuity equations.

$$\tau_{ij},j-p_{ji}=0$$

$$p_{ji}=\mu/k\; W_i$$

$$V_{i,i}=0$$

where τ_{ij} is the stress tensor, p is the pore fluid pressure, μ is the viscosity, k is the permeability and W_i is the filtration velocity.

$$V_i=W_i+v_{si}$$

where v_{si} is the macroscopically averaged solid velocity. The pressure distribution inside the artery wall and the compression/elongation of the wall are also studied (Jayaraman, 1983).

The stenosed blood vessel is mathematically modelled as a constricted tube. The usual Navier-Stokes equations are solved with the no-slip condition on the stenosed vessel. The flow resistance and the separation which depend on the size and shape of the stenosis are investigated. (Jayaraman et al., 1983; Padmanabhan and Jayaraman, 1984).

c) Results

Our theoretical results predict the possibility of boundary layers within the matrix in which the fluid velocities are large compared to the mean rate of transport. The existence of such layers could include both the amount and the distribution of mass transfer and accumulation within the artery wall.

The results on flow in stenosed blood vessels show a marked dependence on the shape and size of the stenosis. Severe stenosis leads to separation in flow which our model is able to predict and the points of separation are also located. The additional impedance to flow due to the constriction is also estimated and a good comparison with experimental results is obtained.

Till now I have been briefly describing the work being done at the IIT Delhi Centre. I would now like to present some recent work in which I have been actively associated.

The Bhopal Gas Leak: Computations from a Model for the Dispersion of the Pollutant

Introduction

The Bhopal disaster has left us in a state of bewildered shock and dismay. The world's worst ever industrial disaster has left an indelible scar on the face of civilization itself. While we are recovering from the state of helplessness with characteristic biological resistance, we must direct our efforts to ensure that such an accident never occurs again. The threat to our air quality is not new. It is, in fact, complementary to industrial development. Since industrial progress has to continue we must take sufficient safety measures to ensure that our air quality is not impaired. In recent years, mathematical models have been developed the world over for predicting pollutant concentrations in the atmosphere. In this report, we have formulated a mathematical model to simulate dispersion of MIC over Bhopal. The Model output gives estimates of the ground level concentration, vertically integrated concentration, the approximate time of arrival of the plume at various affected localities, and also deals with the reaction of MIC with the humid atmosphere. Model results have been correlated with observations on the affected vegetation, animals and fatality statistics. The overall correlation is extremely encouraging. The countdown to the Bhopal disaster started around 12.30 a.m. in the early hours of December, 1984 when untreated MIC vapour escaped through the nozzle of the 33 m high atmospheric vent-line out into Bhopal's cool night air.

Model formulation

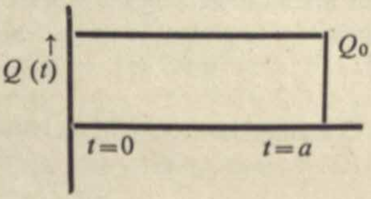
We have considered the unsteady form of the usual atmospheric advection diffusion equation:

$$D_y \frac{\partial^2 c}{\partial y^2} + D_z \frac{\partial^2 c}{\partial z^2} - u \frac{\partial c}{\partial x} - \frac{\partial c}{\partial t} - RC = 0 \tag{1}$$

where c is the pollutant concentration at (x, y, z, t) and y is the constant average wind speed along the down-wind x direction and D_y and D_z are the eddy diffusivities in the crosswind and vertical directions. The source condition is described as

$$c\,(0, y, z, t) = \frac{Q\,(t)}{u}\,\delta\,(z-h)\,\delta\,(y) \tag{2}$$

where $Q\ (t)$ is the step function shown below



Q_0 = source strength (40 tonnes in 90 minutes)
a = duration of emission (90 minutes)
h = effective stack height (39.6 m).

The initial condition is given by

(i) $c\,(x, y, z, 0)=0$ and boundary conditions are

$$D_z\frac{\partial c}{\partial z}=0 \text{ at } z=0,\ H;\ H=\text{Mixing height} \tag{3}$$

and $c\,(x, \infty, z, t)=0$.

The term R in (l) represents the total removal rate due to chemical removal (K_1) and dry deposition (V_d/d) where V_d is the deposition velocity and d the depth of the gas cloud. Thus $R=K_1+V_d/d$. Parameterizations for these two processes are indicated below:

a) To parameterize K_1 we first had to estimate the aqueous phase diffusion coefficient D_{aq} of the MIC water vapour system. This was estimated by standard procedures and it was of the order of 0.98×10^{-5} sq cm per second. Then we estimated the characteristic time for the reaction:

$$CH_3NCO+H_2O\rightarrow CH_3NH_2+CO_2$$

(Methyl amine)

τ could be estimated from the relation $\tau\sim D^2/4\pi^2D_{aq}$, where D corresponds to the drop diameter for the atmospheric moisture particles. For a first order irreversible process the reaction rate is simply given by τ^{-1}. These calculations pertain to a single drop and to obtain the overall removal rate we have to further multiply by the liquid water content. In this way K_1 was estimated to be of the order of 7.3×10^{-4} per second. For the present Model we have only considered the chemical reaction which leads to the formation of methyl amine the major metabolite in the environment. Methyl amine could further react to yield di- and tri-methyl urea.

b) We can assess the importance of the dry deposition term from the ratio V_d/d. Taking $V_d\sim 2\text{cm } s^{-1}$ and $d\sim 30m$, we obtain $V_d/d\sim 0.00067\ s^{-1}$, which is comparable to K_1.

Solution

The solution obtained is given by:

$$c\,(x, y, z, t)=\frac{Q_0 e^{-y^2/2\sigma_y^2}\,e^{-Rx/u}}{\sqrt{2\pi\sigma_y u H}}$$

$$F(t)\left[1+2\sum_{n=1}^{\infty}\cos\frac{n\pi z}{H}\cos\frac{n\pi h}{H}e^{-\sigma_z^2 n^2\pi^2/2H^2}\right] \tag{4}$$

where

$\sigma_y^2=2D_y\,x/u$ and $\sigma_z^2=2D_z x/u$

σ_y, σ_z being the spreads in the lateral and vertical directions. $F(t)$ is the *pulse function.*

Model Evaluation

A computer programme was developed for the ICL 2960. The wind speed at the effective stack height was estimated by using the power law wind profile and the spreads σy, σz were estimated from Briggs (1973) urban interpolation curves.

$$\sigma_y(x) = 0.11x\,(1+0.004x)^{-1/2}$$

$$\sigma_z(x) = 0.08x\,(1+0.001x)^{-1/2}$$

corresponding to stable condition.

The source strength Q_0 was easily obtained from the fact that 40 tonnes of MIC leaked out in about 90 minutes. Further the stack height was about 33 m, and the plume rise was calculated to be about 6.6 m under stable conditions.

Meteorological variables

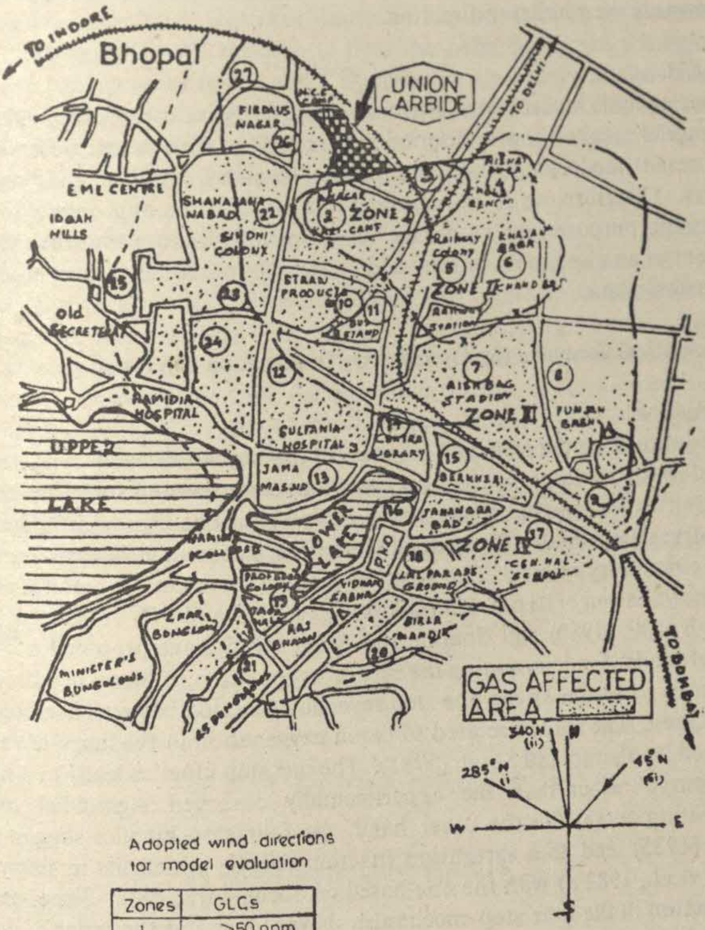
It was assumed that stable right-time conditions prevailed. The meteorological variables like the wind speed and direction at the site on the day of the episode were of course not available. As such we had to depend on mean climatological data for Bhopal as well as on interviews with surviving residents at various localities. The wind that night had changed its course quite swiftly during the duration of the episode, possibly because of the typical characteristic topography of Bhopal which is surrounded by smooth surfaces like lakes, gently rolling terrain as well as undulations due to the presence of hillocks. In view of the above facts, we adopted the following wind directions apportioned appropriately:

i) a wind from 285° for 45 minutes
ii) a wind from 340° for 30 minutes
iii) a wind from 45° for 15 minutes

We adopted a wind speed value of 10.5 km per hour for our computations.

Model results and correlations with observations

It is observed that the superimposed GLC distribution shown in Fig. 5 seems to correlate very well with the extent of affliction at specific sites. The figure shows concentration contours demarcating various zones of the affected areas. We have also appended the zone-wise mortality statistics. It is clear that within Zone I, lethal levels of MIC prevailed. The time-integrated GLCs were greater than 50 ppm, as against 0.02 ppm which is the THV for MIC. The worst affected areas are J.P. Nagar and the Chola area. Zone II, which includes sites 4 to 6 is also a very badly affected zone. Here the time integrated GLCs are about 15 ppm (750 times the THV). Zones I and II stand apart as the worst affected zones. We have also tried to estimate the net loading effect of MIC on the ground by a process of vertical integration. MIC is characterized by a short residence time (about a few hours) and so MIC could settle down within a couple of hours. These results can be used subsequently for corroborating the findings of the agricultural scientists who are concerned with the study of MIC loading on the soil.



Adopted wind directions for model evaluation

Zones	GLCs
I	>50 ppm
II	>15 ppm
III	>1.5 ppm
IV	< 1 ppm

Fig. 5. Concentration contours based on model computations.

Within Zone III the time integrated GLCs are substantially lower (zone of moderate effect); likewise in Zone IV (zone of moderate effects) the time integrated GLCs is less than 1 ppm.

The model also predicts the approximate time of arrival of the plume front at specific sites and these predictions seem to correspond very well with observations. Finally we also found that the concentration contours based on our Model prediction also correlate very well with the degree of damage to plants and vegetation in the sense that the contours for Zones I, II and III tilt towards the southeast direction.

Conclusions

Our analytic model is straightforward and fairly inexpensive to implement. The model results show encouraging correlations with actual observations. The present model emphasizes the plume chemistry, while simplifying other aspects. Therefore, we do not consider this model to be appropriate for final assessment purposes, but rather an important contribution towards the development of an assessment model, and as an interim model for use in preliminary assessments.

Mathematical Formulae for O_2 and CO_2 Dissociation Curves

Introduction

The studies on the transport of gases in the human circulatory system are needed both to improve the diagnostic procedures and for more reliable design of extracorporeal oxygenation equipment. The O_2 and CO_2 dissociation curves are valuable for understanding the mechanism of their transport in the circulatory systems. The position of these curves in the blood is altered with the variation of its pH, temperature, 2 : 3 DPG and PO_2 or PCO_2. Recently Singh et al. (1980) and Sharan and Singh (1985) have proposed a mathematical model for determining the rate of oxygenation of blood in pulmonary capillaries by assuming the one step reversible reaction between haemoglobin and oxygen. The studies related to blood oxygenation in the lungs have been reviewed by Sharan and Singh (1981). The one step kinetics leads to a hyperbolic curve rather than the experimentally observed sigmoidial oxygen dissociation curve. On the other hand, the four step kinetics suggested by Adair (1925) lead to a saturation function for O_2 which fits in fairly well (Singh et al., 1982 a) with the one based on documented data. Since, each of the reaction in the four step mechanism is very fast and the order of magnitudes of its association and dissociation rate constants are not known, it is difficult to formulate a realistic model for the transport of O_2 and CO_2 in the pulmonary and systemic circulations. Hill (1910) has suggested an empirical relation which provides a fairly good approximation for oxygen dissociation curve. However, it does not exhibit the explicit dependence on PCO_2 and it is not suitable in dealing with the simultaneous transport of O_2 and CO_2 in pulmonary and systemic circulation (Singh et al. 1982b). For this purpose, recently, Sharan and Singh (1984) have proposed a modified form of the one step kinetics and modified the well known Hill's equation, which shows an explicit dependence on CO_2. The modified form of one slep kinetics has been incorporated in the mathematical model for the process of blood oxygenation in the lungs. Since the pH plays an important role in the interaction of O_2 and CO_2 in the blood, the mathematical formulae have been developed to represent O_2 and CO_2 dissociation curves in the blood taking into account its PO_2, PCO_2 and pH. We propose to describe here briefly the mathematical formulae for representing O_2 and CO_2 dissociation curves in the blood by considering the plasma and the red blood cells separately. This formulation will be helpful in developing the realistic model for the simultaneous transport of O_2 and CO_2 in the pulmonary and the systemic circulations.

Mathematical description

In the blood, the plasma and the red blood cells are responsible for the transport of O_2 and CO_2. O_2 is carried by the blood in combination with haemoglobin inside the red blood cells. CO_2 is transported by the plasma in two forms (i) free CO_2 and (ii) bicarbonate ions, whereas it is transported by red blood cells as (i) free CO_2, (ii) bicarbonate ions, and (iii) in combination with haemoglobin. The relationship between the total CO_2 combined with the blood in all these forms and PCO_2, in graphical form in called CO_2 dissociation curves. The relationship of the PO_2 and the fraction of oxygenated haemoglobin in total haemoglobin in a graphical form is known as the oxygen dissociation curve. O_2 and CO_2 in the blood undergo the following reversible reactions:

i) RBC

$$\text{a)}\quad H^+ + \mathrm{Hb\,NH_2} \underset{k_1'}{\overset{k_2}{\rightleftharpoons}} \mathrm{Hb\,NH_3^+}$$

$$\text{b)}\quad H^+ + \mathrm{O_2\,Hb\,NH_2} \underset{k_2'}{\overset{k_2}{\rightleftharpoons}} \mathrm{O_2\,Hb\,NH_3^+}$$

$$\text{c)}\quad \mathrm{O_2} + \mathrm{Hb\,NH_2} \underset{k'}{\overset{k_3}{\rightleftharpoons}} \mathrm{O_2\,Hb\,NH_2}$$

$$\text{d)}\quad H^+ + \mathrm{HCO_3^-} \underset{k_4'}{\overset{k_4}{\rightleftharpoons}} \mathrm{CO_2}$$

$$\text{e)}\quad \mathrm{CO_2} + \mathrm{Hb\,NH_2} \underset{k_5'}{\overset{k_5}{\rightleftharpoons}} \mathrm{Hb\,NH\,COO^-} + H^+$$

$$\text{f)}\quad \mathrm{CO_2} + \mathrm{O_2\,Hb\,NH_2} \underset{k_6'}{\overset{k_6}{\rightleftharpoons}} \mathrm{O_2\,Hb\,NH\,COO^-} + H^+ \qquad (1)$$

ii) Plasma

a) $$H^+ + HCO_3^- \underset{k_7'}{\overset{k_7}{\rightleftharpoons}} CO_2 \tag{2}$$

Let C_1, C_2, C_3, C_4, C_6, C_9, C_{10} be respectively, the concentration of O_2, O_2 $HbNH_3^+$, O_2 $HbHH_2$, O_2 HbNH COO^-, HbNH COO^-, $HbNH_3^+$, and $HbNH_2$. C_5, C_7 and C_8, are respectively the concentration of CO_2, HCO_3^- and H^+ in plasma. The symbols with primes denote the corresponding quantities in the red blood cells.

I. Mathematical relation for O_2 *dissociation curve*

From the material balance of the species and the definition of oxygen dissociation curve, we find the following expression for the saturation function of O_2:

$$\frac{S}{100} = \frac{K_0 P_0{}^N}{1 + K_0 P_0{}^N} \tag{3}$$

in which

$$K_0 = \frac{(1 + (K_2\, C_8/r) + (K_6\, r\, \gamma_1\, P_C/C_8))\, KC_8^{-8}}{1 + (K_1/r)\, C_8 + (K_5\, r\gamma_1\, P_C/C_8)} \tag{4}$$

where r is the Gibbs-Donnan ratio; γ_1 is the solubility of CO_2 in the red cells; P_o and P_c are partial pressures of O_2 and CO_2; N and L are constants,

$$K = K^1\, r^l\, C_8^{-l}\, L^N \tag{5}$$

α is the solubility of O_2, and

$$K_i = \frac{K_i}{K_i'}\ ;\ i = 1, 2, 3, 4, 5, 6, 7 \tag{6}$$

II. Mathematical relation for CO_2 *dissociation curve*

Total CO_2 content in the blood = Vol. of RBC × conc. of CO_2 in cells + Vol. of Plasma × conc. of CO_2 in plasma $= H_c\, C_r + (1 - H_c)\, C_p$ (7)

where H_c is the haematocrit.

From (1), (2), (5), (6) and (7), we find that the total blood CO_2 content is given by:

$$\frac{Sc}{100} = \frac{(m_1 + m_2 P_c)}{m_3 + m_4 P_c}\, P_c \tag{8}$$

where m_1 and m_2, m_3 and m_4 are the functions of PO_2 and C_8 but independent of P_c.

$$m_1=\left[\gamma+\frac{\delta_0 K_1}{r}+KC_8^{-l}\,P_0^N\left(\gamma+\frac{\delta_0\,K_2}{r}\right)+\frac{\gamma C_8}{r}\,(K_1+K_2KP_0^N\,C_8^{-l})\right.$$

$$\left.+\frac{1}{C_8}\,\{\delta_0\,(1+KC_8^{-l}\,P_0^N)+\gamma_1\,H_c\,H_7\,(K_5+K_6KP_0^NC_8^{-l})\}\right]f$$

$$m_2=\left[\frac{\gamma_1\,r}{C_8}\,(\gamma+\delta_0/C_8)\,(K_5+K_6\,K\,P_0^N\;C_8^{-l})\right]f$$

$$m_3=1+\frac{K_1}{r}\;C_8+\left(1+K_z\frac{C_8}{r}\right)KP_0^N\;C_8^{-l}$$

and

$$m_4=\frac{r\,\gamma_1}{C_8}\,(K_6\;KP_0^N\;C_8^{-l}+K_5)$$

in which

$$\gamma=\gamma_1\,H_c+(1-H_c)\,r_2$$

$$\delta_0=\gamma_1\,H_c r/K_4+\gamma_2\,(1-H_c)/K_7$$

where γ_2 is the solubility of CO_2 in plasma.

The pH in the plasma is calculated from the PCO_2 through the linear relationship:

$$\text{pH}=7.59+y-0.2741\,\ln\frac{PCO_2}{20} \tag{9}$$

in which

$$y=0.003\;H\left(1-\frac{S}{100}\right)$$

where H is the total Hb concentration in blood in grams per 100 ml.

The constants appearing in (3) and (8) have been computed by fitting (3) and (8) in conjunction with (9) simultaneously with the experimental data of O_2 and CO_2 dissociation curves by the method of least square optimization coupled with the sequensive iterative procedure. The computed values of the constants are found to be close with the experimental ones available in the literature.

Results

i) Oxygen dissociation curve is described by (3). (3) is the "Generalized Hill's Equation" with the important difference that the coefficient K_0 which was taken as an empirical constant by Hill, in fact, depends on the PCO_2 and pH of the plasma as shown by (4).

ii) (8) represents a hyperbola. This new functional form, proposed here, for CO_2 dissociation curve shows an explicit dependence on PO_2 and pH of the plasma.

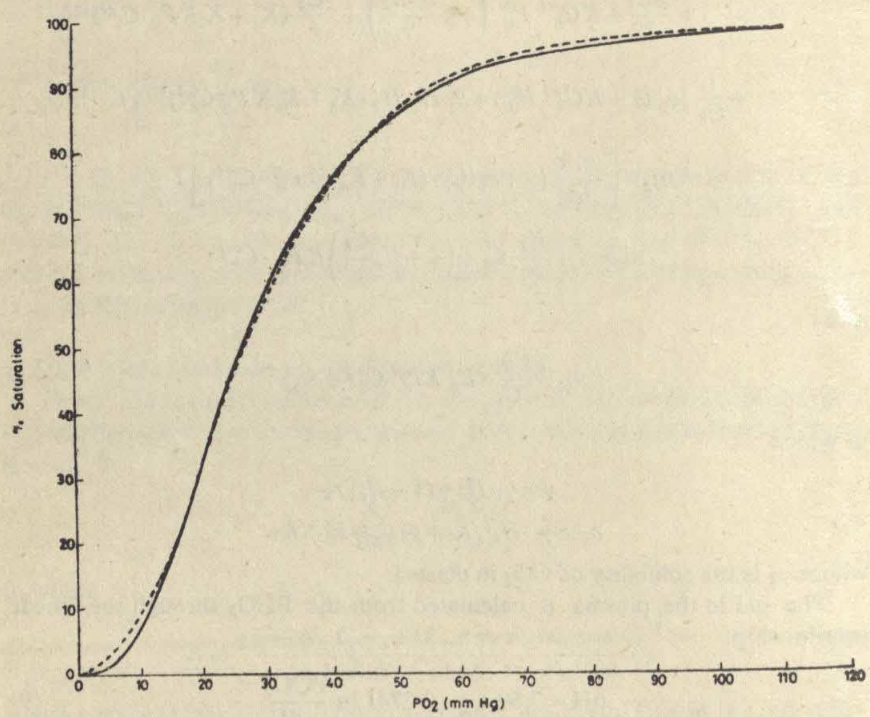


Fig. 6. Comparison of oxygen dissociation curve computed from our equation (—) with the one based on documented data of Severingbaus (1966) (- - - -) pH=7.4 and PCO_2=40 mm Hg.

iii) O_2 and CO_2 dissociation curves computed from our formulae, fit in fairly well with the experimental data (Figs. 6 and 7).

iv) The results for O_2 saturation and whole blood (CO_2) content, obtained from our simpler equations based on formulated physical principles, are in good agreement with those computed from Kelman (1966, 1967) empirical relations.

Concluding Remarks

At the end I would like to conclude by mentioning that while dragging mathematics down to the level of human endeavour, one must keep in mind that working in isolation in an ivory tower does not meet required objectives. Emphasis of Applied Mathematicians should therefore be on working hand in hand with the operational scientists/user agencies involved in tackling real life problems. Universities should be encouraged to take up long-term projects in collaboration with appropriate industries, defence science laboratories

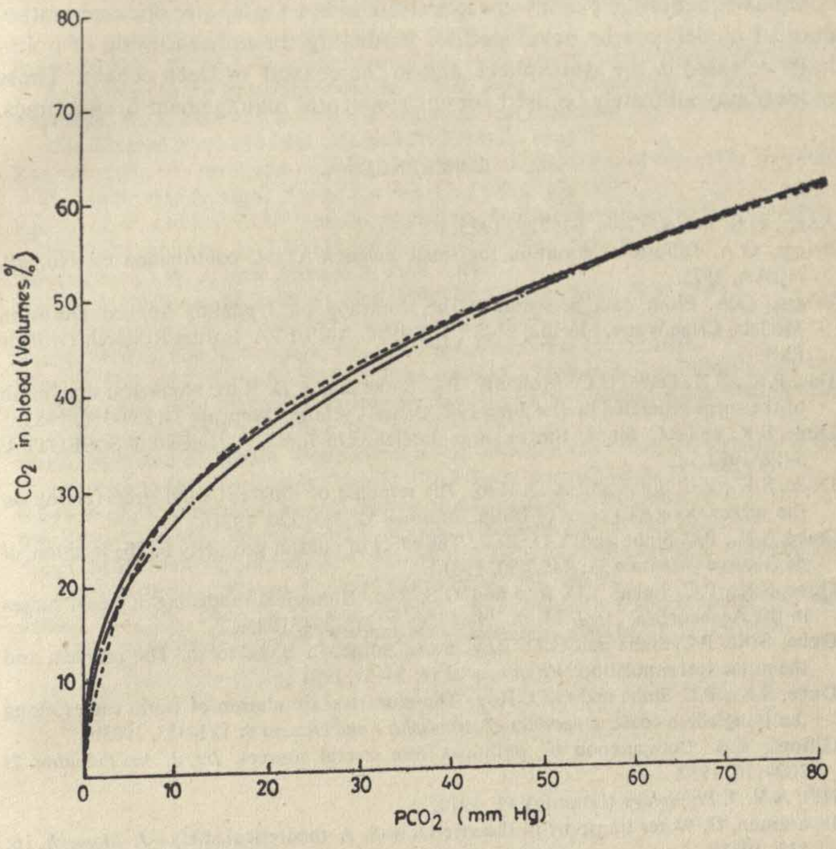


Fig. 7. Comparison of CO_2 dissociation curves computed from our equation (—) and Kelman's empirical relation (1967) (–·–·–·) with the one based on experimental data of Neil taken from Samson Wright (1972, pp. 179) (- - - - -) PO_2= 100 mm Hg H_{crit} =45% and H=15g/100 ml.

aeronautics, space science organizations and other agencies. Since there are a large number of universities in the country where Applied Mathematics activities are going on, it would be desirable to tap such a rich reservoir of talent to tackle some relevant problems of national importance.

The subject of the focal theme is "Science and Technology in Environmental Management". There are so many facets of it. What role mathematics plays in this can easily be visualized. The Atmospheric or Oceanic General Circulation is governed by the basic hydrodynamic equations of continuity, momentum, mass transport and thermodynamic energy equation. These equations have been known to mathematicians for a long time. With the advent of fast computers it has now become possible to solve these non-linear complex equations relevant to practical situations. Computer oriented mathematical models can be developed for predicting the concentration of pollutants released in the atmosphere and in the coastal or deep oceans. These models may ultimately be used for environmental management programmes.

REFERENCES

Adair, G.S. *J. Biol. Chem.* 63: 529, 1925.

Briggs, G.A. Diffusion estimation for small emission-ATDL contribution file No. 79, NOAA, 1973.

Briggs, G.A. From data presented at the workshop on Updating Applied Diffusion Models, Clean Water, Florida, 24–27, Jan. 1984. AMS/EPA. Boston/Research Triangle Park.

Das, P.K., S.K. Dube, U.C. Mohanty, P.C. Sinha and A.D. Rao. Numerical simulation of the surge generated by the June 1982 Orissa Cyclone. *Mausam* 34: 359–366, 1983.

Dube, S.K. and P.C. Sinha, Storm surge prediction in India, A review-Bul SOSEUTI 4: 5–12, 1982.

Dube, S.K., P.C. Sinha and A.D. Rao. The response of different wind stress forcing on the surges along east coast of India. *Mausam* 32: 315–320, 1981a.

Dube, S.K., P.C. Sinha and A.D. Rao. The effect of coastal geometry on the location of peak surge. *Mausam* 33: 445–450, 1981 b.

Dube, S.K., P.C. Sinha, A.D. Rao and G.S. Rao. Numerical modelling of storm surges in the Arabian Sea. *Appl. Math. Modelling* 9: 289–294, 1985a.

Dube, S.K., P.C. Sinha and G.D. Roy. Storm surges in Bangladesh. The problem and the numerical simulation. *Vayumandal* 14: 34–39, 1984.

Dube, S.K., P.C. Sinha and G.D. Roy. The numerical simulation of storm surges along the Bangladesh coast. *Dynamics of Atmosphere and Oceans* 9: 121–133, 1985b.

Gifford, F.A. Computation of pollution from several sources. *Int. J. Air. Pollution.* 2: 109–110, 1959.

Hill, A.V. *J. Physiology* (London) 41, 1910.

Jayaraman, G. Water transport in the arterial wall, A theoretical study—*J. Biomech.* 16: 833, 1983.

Jayaraman, G., N. Padmanabhan, M.P. Singh and Anil Kumar. Developing flow in a thin walled elastic tube with application to vascular system—silver Jubilee issue of the *J. Nat. Acad. Maths.* India 1 (1983) 25.

Johns, B., S.K. Dube, U.C. Mohanty and P.C. Sinha. Numerical Simulation of the surge generated by the 1977 Andhra Cyclone. *QJRMS* 107: 919–934, 1981.

Johns, B., S.K. Dube, P.C. Sinha, U.C. Mohanty and A.D. Rao. The simulation of continuously deforming lateral boundary in problems involving shallow water equations. *Computers and Fluids* 10: 105–116, 1982.

Johns, B., A.D. Rao, S.K. Dube and P.C. Sinha. Numerical Modelling of the tide surge interaction in the Bay of Bengal. *Phil Trans Roy. Soc.* London, Ser. A 9: No. 1, 1985.

Johns, B., P.C. Sinha, S.K. Dube, U.C. Mohanty and A.D. Rao. On the effect of bathymetry in numerical storm surge simulation experiments. *Computers and Fluids* 11: 161–174, 1983a.

Johns, B., P.C. Sinha, S.K. Dube, U.C. Mohanty and A.D. Rao. Simulation of storm surges using a three dimensional numerical model. An application to the 1977 Andhra cyclone. *QJRMS* 109: 211–224, 1983b.

Kelman, G.R. *J. Appl. Physiol.* 21: 1375, 1966.

Kelman, G.R. *Resp. Physiol.* 3: 111, 1967.

Mehrotra, R., G. Jayaraman and N. Padmanabhan. Pulsatile Blood Flow in a stenosed artery. *Med. Biol. Engg. and Computing* 23: 55, 1985.

Padmanabhan, N. and G. Jayaraman. Flow in a curved tube with constriction. An Application to the Arterial system. *Med. Biol. Engg. and Computing* 22: 216, 1984.

Raghavan, N., S. Basu and B.P. Murty. Mathematical modelling of traffic carbon monoxide dispersal in urban Delhi. *Mausam* 37: 1986. (in press).

Raghavan, N., P. Goyal and S. Basu. A Gaussian model for predicting SO_2 concentration in the city of Agra. *Atmos. Environ.* 17: 2199–2203, 1983.

Raghavan, N. and B.P. Murty. Model prediction of mean carbonmonoxide concentration for Delhi. *Mausam* 36: 179–184, 1985.

Severinghaus, J.W. *J. Appl. Physiol* 21: 1108, 1966.

Sharan, Maithili and M.P. Singh. Med. and Life Sciences Engg. 7: 83, 1981.

Sharan, Maithili and M.P. Singh, *J. Biomed. Engg.* 6: 297, 1984.

Sharan Maithili and M.P. Singh, *Int. J. Biomed. Computing* 16: 59, 1985.

Sharma, O.P., H.C. Upadhyay, R.C. Raghava, U.C. Mohanty, K.J. Ramesh and M.C. Sinha. Report on Numerical experimentation of Summer Monsoon Circulation: Onset of Monsoon—CAS Tech. Rep. No. A/TR/1, 1985.

Singh, M.P. and S. Ghosh. Perspectives in air pollution modelling studies with special reference to the Bhopal Gas Tragedy—CAS Tech. Rep. C/TR/2, 137, 1985.

Singh, M.P., K. Khetorpal Mathili Sharan. *J. Math. Biol.* 9: 303, 1980.

Singh, M.P., Maithili Sharan and S.B. Verma. *J. Biomed. Eng.* 4: 279, 1982a.

Singh, M.P., Maithili Sharan, R.K. Saxena and Indu Malhotra. Infinite Element Flow Analysis, (Ed.) E. Kawai, Univ. of Tokyo Press, 867, 1982b.

Sinha, P.C., S.K. Dube, A.D. Rao and G.S. Rao. Numerical simulation of the surge generated by the November 1982 Gujarat cyclone. *Vayumandal* 14: 31–33, 1984.

4

Present Trends and Future Directions of Statistics in India

G. Sankaranarayanan

During the last 50 years, momentous developments have taken place in different branches of statistics leading to outstanding achievements in many interdisciplinary areas. This has been instrumental in exciting refinements and generalizations in the basic structure of statistical methodology. In an environment of this constant change and improvement in the statistical methodology and applications, it is extremely difficult to predict the future direction of Statistics in India.

Modern statistics (Mahalanobis, 1950) is the outcome of the combination of two originally distinct disciplines, one which is primarily descriptive and concerned with the collection of data and the other essentially analytic, associated with the concepts of chance and probability. Statistics comprises the science of decision-making in the face of uncertainty. It would be too much to say that statistics, in its present state of development, can handle all situations involving uncertainties and risks. However new methods are constantly being developed and it can be said that modern statistics provides the framework for looking at those situations in a logical and systematic way. Numerical data derived from surveys and experiments constitute the new material on which interpretations, analysis and decisions are based, and it is essential to know how to squeeze usable information from such data. This in fact, is the major objective of statistics.

Mid-eighteenth century studies on probability, motivated in part by interest in the game of chance, led to the mathematical treatment of errors of measurement and this theory now forms the foundation of statistics. In the same century, interest in the description and analysis of political units led to the development of methods which nowadays come under the heading 'Descriptive Statistics'. This includes any treatment designed to summarize or describe, important features of a set without attempting to infer anything that pertains to more than the data themselves. Although descriptive statistics is an important branch of statistics and it continues to be widely used, statistical information usually arises from samples and this means that its analysis will require generalizations which go beyond the data. As a result, there is a shift in emphasis from descriptive statistics to the methods of statistical inference or Inductive Statistics in modern times.

It is imperative that we evolve a comprehensive teaching programme in statistics for the benefit of scientists, engineers and physicians as early as possible. Like mathematics, statistics is a handmaiden of the sciences—physical, biological and social. Modern statistical theory in its present state of development is of great importance in processing evidence and making decisions in business, government, community health care and so on.

The birth, before Boltzmann and of course before Gibbs, of the statistical approach to problems in physics for instance has proved to be of great use. The successful impact of probability in physics are very conspicious when one considers the developments in the kinetic theory of gases, statistical mechanics and quantum mechanics. The stochastic theory of chemical reactions has received considerable attention in this decade and a number of stochastic models have been proposed for enzyme reactions and polymer reactions. Studies on the statistical behaviour of microbial cell population attracted the attention of engineers and scientists both in chemical engineering and microbiology.

Since the last quarter of the nineteenth century, probability theory and stochastic processes have occupied a modest position in biology and medicine. Some essential vital processes such as the multiplication of organisms or the development of species, have created empirical situations which have led to mathematical models of quite general character. Simulated by the problems of Darwinist biology, many researchers of this century have created stochastic models for the numerical increase of populations, starting from synthetic nomologic statements in biology.

It is worthwhile here to note that acturial work brought with it a number of interesting problems (Sankaranarayanan, 1981). The net result of the risk business of an insurance company during a given period could be regarded as the sum of the net results of all the individual insurances which can be considered as mutually independent. This leads one to the central limit problem in probability theory. If we regard the total risk business as an economic system developing with respect to time subject to random fluctuations, this leads to the modern theory of stochastic processes. Very little work in acturial sciences is going on at present. This is an area which should be paid greater attention.

Random fluctuations exist everywhere and are often treated as the error term. It is the statistical methodology that has extracted the information contained in this variability. Thus we note that statistics is a well established science, a discipline in its own right and an important part of scientific methodology. Since the subject of statistics cuts across interdisciplinary boundaries, it is inevitable that it deals with problems which different research workers encounter in widely different areas.

Let us begin by remarking that most phenomena in real life, and in the biological, physical, social or technological sciences, have a large random component. As mentioned by Gani (1974) it would thus seem natural to use probabilistic methods to solve a number of the problems arising in those fields. Our understanding of applied probability is that it consists of the application of the theory and calculus of probability to the solution of problems in these, as well as other areas. I can think of no better way to substantiate this point than by providing you with few examples of such problems.

Kendall (1974) in a paper read to the Royal Statistical Society has investigated some interesting models of bird navigation. Ornithologists have long known that birds have a homing propensity and have often wondered how it operates. It is now thought that birds may navigate by reference to the sun and the stars in some instinctive fashion. Kendall has proceeded to construct two mathematical models which would simulate bird navigation fairly realistically.

As usual in applied mathematics what all applied probabilists can do is to guide the practical man towards the point at which the really difficult thinking and experiments can begin. I believe that we can only achieve depth in applied probability by considering real life problems and by validating our models on the basis of real data.

Applied probability refers to that part of abstract deductive reasoning generally referred to as Pure mathematics. It is characterized by a language where the abstract concepts are couched in terms of real world objects (counters, dams, queues, epidemics, rumours, expectation, experiments, observations, models, etc.) in which non-determinism is present. Although the vocabulary is borrowed from real objects, they have no more relationship to reality than do 'bundles', 'sheafs', 'categories', 'lines' or 'groups' in other provinces of this heavenly domain (Pyke, 1974). Applied probability is that part of mathematics which studies extensions, generalizations, simplifications and consequences of probabilistic results which have been used in some area of application during recent years. Applied probability uses both deductive and inductive reasoning to describe or explain real phenomena in which randomness plays a basic role. Out of one particular problem at Hunter's Point came the Markov renewal (or semi-Markov) processes. The problem was one of identifying radioactive sources electronically rather than chemically by means of a multiple channel analyser. This instrument would record not only the total number of radioactive impulses, but would record the number of impulses according to their amplitudes.

Statistics encompasses many real life problems and every scientific field including the biological, physical and social sciences, engineering and technology. Applied probability feeds on practical problems, but requires a high level of theoretical competence in probability. It would be difficult, if not impossible, for any journal or set of journals to collect together the diverse strands of the subject, but the effort is nevertheless worth making.

The Neymann-Pearson theory has had tremendous impact on the problem of automatization of signal detection. A learning programme turns the automation into an ideal observer. Surprisingly this aspect also comes under the learning theory to which psychologists like D. Derfman and others have conducted experiments and effected modifications. The theory of random polynomials gives an example of a pure mathematical context in which statistical thought makes it possible to solve new kinds of mathematical problems.

Looking back at the enormous amount of work transacted already, one wonders how many research workers there are in various fields all over the world, who are at this time struggling with problems whose solutions already exist in statistical literature.

The statistical background and environment of the country have undergone momentous changes. During the last 50 years the changes mentioned above have been both quantitative and qualitative (Sankaranarayanan, 1980). The quantitative change can be seen from the number of Universities that have come up during the last 30 years, especially after the formation of the University Grants Commission. An index of the quality of any subject in any country is the quantity and quality of research output and this in turn is justified in terms of the number of publications in journals of international standing.

Research activities in statistics in our universities and institutions are mostly basic and fundamental. However in border line areas like physics, chemistry, engineering, biology, agriculture, physiology, psychology, linguistics, economics and management science, research activities in our country have been much less compared to the phenomenal progress made in the scientifically developed countries of the world. University departments devoted to the study of statistics should be encouraged to take interdisciplinary research work leading to quantifying concepts in physical, biological, medical and engineering sciences. Though one would expect a much higher turnover of research work and publications from University Departments, one could safely say that the output of research far outweigh the inputs in our Statistics or Mathematics Departments in our Universities. There are still a few University Departments in the country doing remarkably good research work under very adverse conditions.

Taking into account the recently developing parochial character of most of the journals which have now attained an international stature, I have come to the firm conclusion that the best work that is produced in the country does not see the light of day, as many of them get rejected by these so called international journals. Since we have very few national journals, the enterprising student finds it difficult to get his papers published. I thus take this opportunity to appeal to the government and all other national bodies to start new journals and maintain them, keeping their standards on a par with the international journals. If a small country like Japan can have over 50 journals in mathematics and statistics, I don't see why we can't have at least 50 journals in exact sciences in our country. This alone can boost the morale of research workers in our country.

The qualitative change mentioned by me is that, with the setting up of the UGC, a positive effort has been made to improve the quality of teaching and research in mathematics and statistics in the country. Teaching of statistics (Bansal, 1979) in India may be broadly classified as: (i) academic which is carried out in Universities and research Institutions including ISI, (ii) training of industrial statisticians by industries, and Indian Institutes of Management (IIM), and (iii) training of government statisticians undertaken by governmental agencies. It is the duty of our governmental agencies to encourage research in all these three kinds of institutions in all possible ways.

There has been too much talk about teaching in Universities, and that a University is not a proper place for teaching in the common meaning of the world. To some extent this statement is partially true. The main function of a University should be, in my view, to provide an environment in which students feel stimulated and challenged to bring out the best in themselves an environment of constant intellectual ferment.

All of us, I believe, would like to be doing something useful and relevant. But for those of us working at the forefront of knowledge, it is an extremely difficult task to distinguish between the potentially useful and a dead-end street.

Whether we are working in mathematical statistics or in theoretical physics we share the common constraint that good research ideas are extremely rare to come by and perhaps what we need is not to change our conceptual mechanisms which have proved their functionality over a long period of time, but rather to be more sensitive in our minds to the needs of the society, and see how we can expand the importance of our ideas by exploring their total significance to as many fields of endeavour as possible.

The number of different fields in which an idea is found to be useful is a good index of the basic worth or quality of that idea. For example, when a research contribution by a mathematician is found to be useful in chemistry (a field which in general is rather far from the core of mathematics), it is a clear indication that it has a basic content of substance and significance.

It is easy to give numerous examples of research activity which started in one direction and happened to produce results in quite a different area. The following example illustrates this point. O.T. Avery (Mark Kac, 1974) was working on an extremely applied problem concerned with pneumonia. In the process of this investigation he discovered that the carriers of genetic information were not proteins, but nucleic acids. This discovery revolutionized the whole field of genetics, although the original problem which led to it was a specific applied problem (medical). Thus it is not the problem or the name attached to it that is pertinent. What matters is the special combination of the men, the problem and the environment and no one can possibly predict exactly these things and their outcomes.

After 40 years of modest research work under very difficult circumstances, I feel justified in making the above comments. In fact I started my research carrier by working on problems connected with limit distributions. My work (Sankaranarayanan, 1956) was in the limit distributions of sums of functions of partial sum of independent identically distributed random variables. The three dimensional case which was considered as a mathematical exercise 30 years ago when examined now has useful applications on the Stochastic theory of hydrology.

Likewise the same is true of my work in the law of iterated Logarithms (Sankaranarayanan, 1956). It is surprising to note that in 1956 this paper did not find acceptance. At the same time the content of this paper has reappeared in 1965 and later in the form of 30 or 40 research papers by numerous authors in various journals. This induced me to re-examine the whole work again and now I find that this work is again relevant in the context of hydrology, pollution control and so on.

Again my work as well as those of my students in Renewal Theory and Reliability models (Sankaranarayanan) have significant application in controlling the environment, pollution, etc. It is needless to add that re-evaluation of our work in Branching Processes with immigration, Branching Processes with immigration and disasters, Queues and Counter Models (Sankaranarayanan) etc. have immense applications in areas like population dynamics, ecology, epidemiology, environment and pollution control.

If we look back at the connection between Astronomy and Operations Research viz Laplace (Mark Kac, 1974), we will realise the significance of the proverb that it is difficult to predict, especially the future. In this context I wish to add that it has become possible to distinguish between the genetic and the environmental factors, because the mean is controlled by the genetic factor while the variance is controlled by the environmental factor.

We should be connected with as many reservoirs of inspiration and understanding as possible and should ask questions and try to answer them precisely. Let us not worry about 'pure', about 'applied', about 'useful', about 'relevant' and so on. While answering those questions, let us, in brief, try to do our best and what survives will be determined by nature's law of survival of the fittest; and what is fittest will be determined by the next generation in the light of what has survived.

Nowadays people give great importance to computer oriented instruction. For this, one should consider as suggested by Meyer Dwass (1974) (i) the availability of an adequate time-sharing computer facility, (ii) the involvement of the instructer in being able to use the computer in the class room as an aid to teaching as easily as he or she uses chalk and blackboard, machine or overhead projector, and (iii) student participation in learning to understand written computer programmes, in being able to modify such programmes on their own. The presence of this device in the class room which allows students to see the computer at work and which allows the instructor or students to interact with the computer will help the students a great deal in understanding many problems in statistics with the aid of the computer. The main danger in this computer approach to teaching statistics is that it may turn into a course in computer programming with statistics achieving secondary importance. Students may get the idea that there is no need to learn mathematics, since anything of interest can be approximately derived by means of simulation of brute-force computation. However, I think that those who have made such a beginning to use the computer in teaching statistics have only scratched the surface and that there is a great deal to learn. I also believe that the prospects are optimistic about the usefulness of the computer as a pedagogic tool.

We now proceed to discuss a few problems connected with the focal theme. They include demography, evolution, epidemic theory, medicine, pollution and environment models.

There is some mistrust of statistical ideas by the official demographers. Thus demographers give projections (extrapolations) under deterministic models rather than predictions of future populations. Census data are collected for a great variety of purposes and while we are waiting for the next census, estimates are needed. This great apparent demand for data has not built up a technology for justifying the census budget.

On the analytic side, statistics should encourage workers in the data system to form problems. A good problem is a good guide. As a working hypothesis, it is appropriate to assume that the collection of the major statistical series and some of their important uses can be formulated as a statistical decision problem. The solutions of such problems would give strong arguments for how much data one has to collect and what kind of terminal losses one has to anticipate.

The bases of a mathematical theory for biological evolution were created around the twenties, mostly by the independent work of Fisher (1930), Haldane (1932) and Wright (1931). The depth and breadth of developments that have taken place since that phase is witnessed by the number of papers in existence today. Felenstein and Taylor (1974) has recently collected the relevant bibliography. Crow and Kimura (1970) have expounded in their lucid book the major mathematical developments. Cavalli-Sforza and Bodmer (1971) have summarized their application to man.

According to Cavalli-Sforza (1974) all evolutionary processes are basically similar, no matter what the objects are that evolve. Biological evolution concerns living organisms. Natural 'selection' is the consequence of the individual variation among organisms of a species in the capacity to survive to adulthood and to leave progeny. These individuals who are more successful in these respects, contribute proportionately, more of their genes to the future generations. In the process of 'transmission' of genes from one generation to the next there happen rare, transmissible changes by a random process called 'mutation'. It is these changes which form individual, transmissible variation, on which natural selection operates when determining evolution. In addition, in every population of finite size there are sampling effects which generate stochastic variation and thus add randomness (random genetic drift) to the process.

One should not underestimate the difficulties of applying a mathematical theory to biological data. Observations are almost always limited in number, and there are many sources of error. Only in a few organisms can one hope, by the present techniques, to estimate with some accuracy, basic quantities, for instance, like mutation rates. Intensities of selection have been evaluated only in a few cases. Even so, it has been reassuring to find that theoretical predictions were verified, within reasonable limits of error. Moreover, the mathematical theory of biological evolution has provided a conceptual framework which has helped considerably the understanding of evolutionary phenomena (Cavalli-Sforza, 1974).

Another simple evolutionary model is that of the rate of decay of evolutionary units: amino-acids in proteins (Cavalli-Sforza, 1974). It was shown by Zuckerkandl and Pauling (1965) that the substitution of amino acids in proteins can be described by a negative exponential distribution. Thus probability of substitution of a given amino-acid is constant over time. A substitution of a given amino-acid position takes on an average about one billion years. A complication that is not fully understood is that different proteins have different substitution rates.

We now discuss a few epidemic models of interest. An epidemic presents a formidable challenge to public health authorities, epidemiologists, biostatisticians and other experts whose skills may have some bearing on the problem involved. The understanding of the dynamics of epidemics will be helpful in preventing infectious diseases and also in controlling bacteriological warfare. The mathematical models have become useful to understand the occurrence and spreading of the epidemics. They also help to arrive at a particular decision related to the control of diseases, such as an immunization programme, optimal allocation of resources or the best combination of control and eradication techniques (Bailey, 1975).

The epidemic models used will differ from one another depending on the diseases involved, community being studied, and questions asked while collecting data.

The study of epidemic processes are of great interest, not only because of the biological and epidemiological implications, but also because more complicated stochastic processes are involved. With continuous time stochastic processes, the transition probabilities are by and large linear functions of the population size. The resulting partial differential equations for probability generating functions or moment generating functions then turn out to be of a linear type which is frequently solvable, or at least sufficiently tractable to yield a number of useful properties. With epidemic models on the other hand, the transition probabilities are usually non-linear functions of the population size. And this leads, even with models that are descriptively very simple, to mathematical analysis of considerable complexity (Bailey, 1964).

Mathematical theory of epidemics received greater attention after 1940. Bartlett (1946, 1949) developed a partial differential equation for the probability generating function of two variables. He considered the number of susceptibles and number of infectives at any instant for developing the partial differential equation. Whittle (1955) has developed a stochastic threshold theorem. Bailey (1956a, b) has obtained a more elaborate model involving a variable latent period after the receipt of infection, followed by an extended infectious period.

In the case of simple stochastic epidemics there were several developments in the beginning. Bailey (1963) has obtained a closed expression for the probability generating function. The perturbation and diffusion approximations to the moment generating functions have been obtained by Bailey (1968). Becker (1968) studied the model with a departure from homogeneous mixing.

In the case of general stochastic epidemics, new developments were initiated by the works of Gani (1965, 1967), Siskind (1965) and Lynne Billiard (1973). Sakino (1959, 1962, 1963. 1967) has studied the age distribution of infectives. The distribution of total epidemic size has been given by Gani (1967) and Williams (1971). The theory of parameter estimation has been studied by Morgan (1965), Sally Ohlson (1964) and Bailey and Thomas (1971).

An area which has received considerable attention in recent years is that of models involving carriers. The study of carrier-borne epidemic models was initiated by Weiss (1965), who developed deterministic and stochastic models involving carriers. He also obtained the solution of the time-dependent models for the case when the number of carriers is one. The model was further developed by Dietz (1966) and Dietz and Downton (1968). Dietz (1967) has studied the time-dependent parameters of the model developed by Weiss. Dietz and Downton (1968) considered the problems of introduction of new carriers and susceptibles from outside population. The cross-infection from within the population was discussed by Downton (1968). Further analysis of Downton's model was made by Gillion Danton (1972). Becker (1970) has given the generalized model of Dietz and Downton. Becker (1973) has given a multi-group model with variation in susceptibility and infectiousness. The application of general multivariate birth and death process to large population approximations of epidemic processes was made by Griffiths (1973).

We can also seriously think and develop suitable investigations to bring to the attention of epidemiologists the possibility of setting up and utilizing structural models based on graph theory.

In modern medicine it becomes more and more urgent every year to solve new epidemiological problems. One of these is the evolution of resistance to antibiotics of a large spectrum of micro-organisms. This resistance is a consequence of the mass administration of antibiotics. In this problem it becomes necessary to apply the mathematical methods of epidemic theory as the key to this study comes out as a purely epidemiological factor, namely the mass character of the use of antibiotics in this technique. At the same time, it can be shown that even if effective antibiotics are administered, reasonable limitations of their use will not result in the spread of a resistant sub-strain.

In an elegant review, Mollison (1977) has outlined a theory of contact processes for epidemics. He has discussed the velocity of their spatial spread both in the deterministic and stochastic cases. Some useful applications are given and outstanding problems listed. Gani (1978) has considered some deterministic models in discrete time for the classical versions of the simple and general epidemics. He has derived threshold theorems for both cases, and has indicated their differences with the continuous-time analogues.

Recent advances and controversies in genetical and related questions, for example, sociobiology, heritability and IQ, recombinant DNA, nucleotide sequencing and cleaning, require various advances in population genetics theory and also changes in direction of the theory.

Medical research has grown dramatically in the past decade, with promise of continued growth ahead. Probabilistic models are needed in many basic areas of genetics, virology, epidemiology, microbiology, physiology, etc. More and more data for testing models are becoming available for example from clinical trials and from national surveys of comparative merits of surgical techniques and drugs.

Shahani and Crease have established that if a particular screening procedure is medically desirable, there remains the practical necessity of determining whether or not the costs involved would be worthwhile. Clearly in these days of scarce resources it is necessary to search for screening policies which will make the procedures as efficient as possible. Many variables, some of them stochastic in nature, influence the efficiency of a screening programme. One difficulty here is that in general it is not possible to express the risks, costs and benefits of a screening procedure in the same common and easily understood measure, for example monetary units. It is felt that the usual cost-benefit analysis is unlikely to suffice in this very complex situation involving pain, suffering and human life. But, nevertheless, some quantitative guides are essential for making good decisions about screening procedures. Suitable mathematical models, if available, would help the medical decision-makers confronted with this complex situation. Essentially such a model will seek to connect the basic elements that are involved in screening.

Let me discuss a pollution problem connected with acoustics. The theory of acoustic noise from a stream of traffic is of great interest at the present time because of various efforts to decrease the effects of this noise. A deterministic theory of this noise was first given by Johnson and Saunders (1968) and the first stochastic development by Weiss in 1970. Mercus (1973) has developed this theory to take into account variations in vehicle types and different kinds of vehicles. He concludes that such variations considerably enhance the variance of noise level. More recently Weiss investigated the effect of a non-exponential distribution of headways as would be appropriate for flows of more than 600 cars per hour per lane. He has also developed (Mercus, 1973) an analogous theory for atmospheric pollution induced by a stream of vehicles. Shaw and Olson (1972) have described environmental noise pollution in Ottawa by a similar model. We can use some of these models with suitable changes to study similar situations in India.

Let me now touch a few aspects of Environment Models. An important class of problems in manpower planning is concerned with the control of age or grade structures. The numbers of people in such categories change over the time through wastage, promotion, transfer, and recruitment. Some of these flows are subject to management control while others vary in a random fashion. Factors such as the need to offer an adequate career prospect or the requirements of the job will often dictate a desirable age or grade structure and the manpower planner's task is then to determine whether this can be achieved and, if so, how.

We shall limit the present discussion by only examining how a structure can be maintained. But it turns out that this cannot be treated adequately without considering questions of attainability. Secondly, we shall suppose that the recruitment flows are the only ones subject to control. This is no real restriction if we consider age distributions since 'promotion' is simply the process of ageing. Natural wastage is not usually subject to control to any case. In the more general case of a graded system, where promotion flows can be controlled, it often causes less internal stress to achieve as much control as possible through recruitment control. Suitable stochastic analysis has to be evolved to study this problem.

Another important problem facing us is the inundation of forests in recent years. This has instilled in us a great desire to preserve the existing forests and start a new plantation programme. The following model will be of immense use in this plantation programme.

According to Gates and Westcott (1978) a plantation is modelled in terms of discs of random size centred on the points of a two-dimensional lattice, together with rules for partitioning the union of these discs into surviving zones associated with each plant. The disc radii are taken to be independent and identically distributed, with a suitable distribution function. We consider the spatial stochastic process of measurements on individual plants and of the distribution. These properties include conditions for non-extinction, existence of moments, the behaviour of co-variances as functions of separation and ergodic and central limit results for plantation and sample averages. They also lead to a rigorous demonstration of certain well-known empirical relations between typical measurements and survival frequencies and to some new relations which are amenable to tests. The model is a formulation of computer simulation which has attained success in describing competition in plantations, but are too costly for forest management.

Competition between neighbouring individuals in a plant or forest crop was widely recognized as a dominating influence in the development and yield of the crop (Fries, 1974; Diggle, 1976; and references cited therein). Gates and Westcott (1977) have surmised that the competition can be for light, through mutual shading, and for water and nutrients, through both root and crown systems. Its most manifest feature is variability in plant sizes which can lead to a separation of the population into dominating and dominated plants and to various degrees of mortality (Ford, 1975; Diggle, 1976; Gates, 1978). The competition dramatically increases the natural variability resulting from the innate characteristics of individual plants. Detailed models of competition in forest plantations have been studied recently by computer simulation (Mitchell, 1969, 1975a, b; Munro, 1974). In order that mortality and competitive development may be accurately modelled, it is clearly necessary to incorporate realistic zone of influence structure and overlap rules. To date, work on zone of influence models has been entirely numerical. Mitchell's studies consist of simulating the expanding discs and their partition on a computer. Thinning strategies can be incorporated in an obvious way. As this approach is subject to the constraint of cost, only a small number of possible cases can be examined by this method. Also the simulation results do not provide as much insight as one would like into qualitative effects at work in the model.

It is hoped that our statisticians and probabilists will apply their mind to those problems under Indian conditions and help us in maintaining a clear environment.

Another environment problem which we would like to mention here deals with the question of ocean temperature dynamics (Sutton, 1978). A careful examination of sound-speed measurements taken at sea reveals the presence of weak fluctuations about the mean sound-speed profile. Since the cause of these fluctuations rests in variations in the temperature field, it has been commonly accepted to refer to the fluctuations as the thermal or temperature microstructure. An acoustic signal that propagates through the ocean will interact with the temperature microstructure, resulting in a scattered field with a directional energy spectrum that can be related to the statistics of the microstructure. It is of interest to determine this relationship for two potential applications. In a direct application, the resolution capabilities of an aperture system can be discussed in terms of its ability to resolve an incoming signal's directional energy spectrum. An inverse application is that the statistics of the ocean temperature microstructure can be determined by the dynamics of the upper ocean. Thus, knowledge of the statistics of the temperature microstructure can be translated into formation of ocean dynamics and the scattering of acoustic signals offers a potential tool for that long-range monitoring of these dynamics. We might further note that acoustic scattering experiments may prove to represent the only practical monitoring procedure for the larger size scale structure.

Jones (1977) has studied space-time correlations for microearthquakes stochastically. Several problems arise in selecting earthquake data for a statistical study. Because the instrumentation required to obtain the data is costly, complex and subject to continuing technical innovations, it is important to check that changes in instrumentation are not possible causes of spurious effects. It is also important particularly in looking at spatial patterns, to ensure uniform coverage throughout the region, so that smaller shocks are not missed from some parts of the region. Studies have shown that larger shocks tend on the average to occur to the south and west of the smaller shocks. This again may be interpreted as an effect of non-homogeneity. In summary it may be suggested that, despite the obscuring effects of non-homogeneity, the analysis can play a useful role in revealing, in a tentative and exploratory fashion, gestures of geophysical interest.

Let me conclude by appealing to our academic community to develop the spirit of enquiry, motivation, independent thinking, originality of approach and above all self-confidence amongst the newly emerging and highly dynamic community of young men and women. Let us work hard along with them with an eye on application to suit Indian conditions. Let us have more and more first-rate Indian journals which will publish research papers of quality by our student community. Let us put a stop to the existing condition of having to turn to foreign journals for publishing our original contributions. I am sure that if we adopt such an independent policy, just as Japan in such a short period after the Second World War, has emerged as one of the most foremost centres in respect of scientific developments, we will also surely emerge as one of the most scientifically developed countries in the world.

REFERENCES

Bailey, N.T.J. On estimating the latent and infectious periods of Measles II. Families with 2 susceptibles only. *Biometrika* 43: 15-22, 1956a.

Bailey, N.T.J. On estimating the latent and infectious periods of Measles II. Families with 3 or more susceptibles. *Biometrika* 43: 322–331, 1956b.

Bailey, N.T.J. The simple stochastic epidemic: a complete solution in terms of known functions. *Biometrika* 50: 235–240, 1963.

Bailey, N.T.J *The Elements of Stochastic Processes with Applications to the Natural Sciences*, Wiley, New York, 1964.

Bailey, N.T.J. A perturbation approximation to simple stochastic epidemic in a large population. *Biometrika* 55: 195–209, 1968.

Bailey, N.T.J. The mathematical theory of infectious diseases and its applications (2nd Ed.) Griffin, London, 1975.

Bailey, N.T.J. and A.S. Thomas. The estimation of parameters from population data on the general stochastic epidemic. *Adv. Appl. Prob.* 3: 211–214, 1971.

Bansal, A.K. Present situation of Education of Statistics in India, Discussion Material No. 2 Institute of Information Sciences, Soka University, Japan, 1979.

Bartlett, M.S. Stochastic Processes. Notes of a course given at the University of North Carolina, 1946.

Bartlett. Some evolutionary S. Pis. *J. Roy. Stat. Soc. Ser.* B 11: 211-229, 1949.

Bartholomew, D.J. Maintaining a Grade or agestructure in a stochastic environment. *J. Appl. Prob.* 9: 1-17, 1977.

Becker, Niels G. The spread of an epidemic to fixed groups within the population, *Biometrics* 24: 1007–1014, 1968.

Becker Niels G. A stochastic model for two interacting population. *J. Appl. Prob.* 7: 544–564, 1970.

Becker, Niels G. Carrier-borne epidemics in a community consisting of different groups. *J. Appl. Prob.* 10: 491–501, 1973.

Cavalli-Sforza, L.L. Cultural and biological evolution: a theoretical enquiry. *Supp. Adv. Appl. Prob.* 7: 90–99, 1974.

Cavalli-Sforza, L.L. and W.F. Bodmer. Variation in the fitness and molecular evolution, Vol. 5, Darvinian, New Darvinian and Non-Darvinian Evolution. *Proc 6th Berkeley Symp. Math. Statist. Prob. Conference on evolution*, 155–175, 1971.

David Kendall. Pole-seeking Brownian motion and bird navigation *J.R. Statist. Sec. B* 36: 365–402, 1974.

Dietz, E. On the model of Weiss for the spread of epidemics by carriers. *J. Appl. Prob.* 3: 375–382, 1966.

Dietz, E. Epidemics and Rumours: A survey. *J. Roy. Stat. Soc. Ser. A.* 130: 505–528, 1967.

Dietz and F. Downton. Carrier-borne epidemics with immigrations, *J. Appl. Prob.* 5: 31–42, 1968.

Diggle, J. A spatial stochastic model of interplant competition. *J. Appl. Prob.* 13: 662–671, 1976.

Downton, F. The ultimate size of carrier-borne epidemics. *Biometrika* 55: 277–289, 1968.

Felenstein, T. and B. Taylor. A bibliography of theoretical population Genetics, National Technical Information Service, U.S. Dept. of Commerce-Report No. RLO-2225-5-18, 1974.

Fisher, R.A. *The Genetic Theory of Natural Selection*. Clarendon Press, Oxford, 1930.

Ford, E.D. Competition and stand structure in some even-aged plant monocultures. *J. Ecol.* 63: 311–333, 1975.

Fries, J. Growth models for Tree and stand simulations, Royal College of Forestry, Stockholm, Dept. of Forest Yield Research, Research notes 30, 1974.

Gani, J. On a partial differential equation of epidemic theory I. *Biometrika*, 52: 617–622, 1965.

Gani, J. On the general stochastic epidemics. Proc. Fifth Berkeley Symposium, University of California Press, 1967.

Gani, J. Some problems of epidemic theory. *J. Roy. Stat. Soc.* 140: 323–347, 1974.

Gani, J. Some interesting current directions in epidemic theory. *J. Appl. Prob.* 11: 262, 1975.

Gates, D.J. Bimodality in even-aged plant monocultures. *J. Theoret. Biol.*, 1978.

Gillion Danton. On Downton's carrier borne epidemic. *Biometrika* 59: 455–461, 1972.

Gates, D.J. and M. Westcott. Spatial competitions in plantations. *J. Spatial Pattern and Processing* 98–103, 1977.

Gates, D.J. and M. Westcott. Zone of influence models for competition in plantations. *Adv. Appl. Prob.* 62–71, 1978.

Griffiths, D.A. Multivariate birth and death processes as approximations to epidemic processes. *J. Appl. Prob.* 10: 15–26, 1973.

Haldane, J.B.S. *The Causes of Evolution.* Harper and Row, New York, 1932.

Johnson, D.R. and E.G. Saunders. The evolution of noise from freely flowing traffic. *J. Sound Vib.* 7: 287–309, 1968.

Kimura, M. and J. Crow. *An Introduction to Population Genetics Theory.* Harper and Row, New York, 1970.

Lynne Billiard. Factorial moments and probabilities for the general stochastic epidemic. *J. Appl. Prob.* 10: 277–288, 1973.

Mahalanobis, P.C. Why Statistics? Presidential address at the 37th Indian Science Congress Meeting, 1950.

Mark Kac. Some reflections of a mathematician on the nature and the role of Stat. *Proc. Conference on Directions for Math Stat.* 5–11, 1974.

Mercus, A.H. Traffic noise as a filtered Markov renewal process. *J. Appl. Prob.* 10: 32–39, 1973.

Mercus, A.H. A stochastic model of micro-scale air pollution from highway traffic. *Technometrics* 15: 353–363, 1973.

Meyer Dwass. The use of computer in teaching statistics. Pro. Conference on Directions for Math. Statistics. *J. Adv. Appl. Prob.* 12–16, 1974.

Mitchell, K.J. Simulation of the growth of even-aged stands of White spruce. Yale University. School of Forestry Bulletin No. 75, 1969.

Mitchell, K.J. Dynamics and simulated yield of Douglas *Fir. Forest Sciences*, 1975a.

Mitchell, K.J. Stand description and growth simulation from low level streo photos of tree growth. *J. Forestry*, 12, 1975b.

Mollison, D. Spatial contact models for ecological and epidemic spread. *J.R. Statist. Sec.* B. 39: 283–326, 1977.

Morgan, R.W. The estimation of parameters from the spread of a disease by considering households of two, *Biometrika*, 52: 271–274, 1965.

Munro, D.D. Forest growth models—a prognosis. In growth models for Tau and stand simulations, (ed.) J. Fries, Rotobeckman Stockholm, 1974.

Pyke, R.A pplied Probability: An editor's dilemma. *Proc. Conference on Directions Math. Statistics* 17–37, 1974.

Sakino, S. Epidemic model under the influence of damped oscillations. *Proc. Inst. Stat. Math.* 6: 117–124, 1959.

Sakino, S. On the age distribution of epidemic I. *Proc. Inst. Stat. Math.* 10: 33–39, 1962.

Sakino, S. On the age distribution of epidemic model and the prediction of poliomycetitis. *Proc. Inst. Stat. Math.* 11: 25–30, 1963.

Sakino, S. On the age distribution in epidemics II. *Proc. Inst. Stat. Math.* 15: 126–133, 1967.

Sally Ohlsen. On estimating epidemic parameter from household data, *Biometrika* 51: 511–512, 1964.

Sankaranarayanan, G. Contributions to the study of some topics in Mathematical statistics—Sequences of independent Random Variables, Distributions of Quadratic forms and Tests of hypothesis (Ph.D. Thesis), 1956.

Sankaranarayanan, G. Limit distributions in the theory of counters. *Ann. Math. Statist.* 32: 1271–1285, 1961.

Sankaranarayanan, G. Theory of Particle counters, *Mathematical student*. 32: 29–38, 1964.

Sankaranarayanan, G. (with C. Suyambulingam). Some Renewal theorems concerning sequences of correlated random variables. *Pacific J. Math.* 30: 785–803, 1969.

Sankaranarayanan, G. (with C. Suyambulingam). Distributions of the maximum number of impulses at an instant in type II counter in a given interval of time. *Metrika.* 18: 227–233, 1972.

Sankaranarayanan, G. Limit distributions in Probability theory. *J. Annamalai Univ.* Part B. Sci., 197–218, 1972.

Sankaranarayanan, G. Renewal Theory. Indian Mathematical Society Conference, Madurai Symposium on QIR, 1972.

Sankaranarayanan, G. Age dependent Branching Processes with immigration Indian Census Centenary Congress, 1973.

Sankaranarayanan, G. Branching Processes. *J. Annamalai Univ.* Part B. Sci, 1973.

Sankaranarayanan, G. (with K.B. Athreya and P.R. Parthasarathy). Super-Critical Branching Process with immigration *J. Appl. Prob.* 10: 695–702, 1974.

Sankaranarayanan, G. Life time distributions in cumulative damage models in Reliability theory. *Mat. Science Conference*, 1977.

Sankaranarayanan, G. (with V. Balakrishnan). A renewal theorem for a strictly stationary discrete Stochastic process. Aeitschrift Mathematicshe Operations furshung and Statistik, Series Optimization. 8: (4) 581–597, 1977.

Sankaranarayanan, G. (with R. Nadarajan). Some results for the transient solutions in the queueing systems $E_k/G/1$. Proc. of the 160th meeting of the Institute of Mathematical Statistics, ISI-New Delhi. December 16–18, 1977.

Sankaranarayanan, G. (with A. Krishnamoorthy). Branching Process with immigration subject to disasters. *J. of Mathematical and Physical Science* IIT, 12 (2): 165–176, 1978.

Sankaranarayanan, G. (with R. Ramanarayanan and K. Usha). Availability of a 2 unit parallel system. IEEE Trans. on Reliability, 1978.

Sankaranarayanan, G. (with P.R. Parthasarathy) Age dependent Branching processes with immigration when inter-arrival times are correlated. *J. Indian Stat. Asso. Poona*, 16: 83–86, 1978.

Sankaranarayanan, G. (with V. Balakrishnan). A renewal theorem for a sequence of dependent variables. *Acta Mathematica Acad. Sci. Hungar.* Budapest. 3101–2: 1–8, 1978.

Sankaranarayanan, G. (with R. Nadarajan) A bulk service queueing problem with Erlang input, National Symposium on QIR. Annamalai Univ., 1978.

Sankaranarayanan, G. Presidential Address at the II annual conference of the Indian Society for Theory of Prob. and its applications held at IIT, Bombay, 1980.

Sankaranarayanan, G. Presidential Address at the III annual conference of the Indian Society for theory of Prob. and its applications held at the Univ. of Delhi, 1981.

Sankaranarayanan, G. (with V. Thangaraj) On the iterated logrithm laws for weighted averages of Martingale differences sequences (communicated).

Sankaranarayanan, G. (with S. Sivaraman). A generalized counter model using representation techniques (communicated).

Sankaranarayanan, G. (with A. Chockalingam). A variation of the counter model (communicated).

Sankaranarayanan, G. (with V. Balakrishnan). $E_k/G/1$ queue treated as Branching processes (communicated).

Sankaranarayanan, G. (with R. Ramanarayanan and K. Usha) The PH/M/c queue with varying environment (communicated).

Sankaranarayanan, G. (with R. Nadarajan). Bulk service queue with additional server (communicated).

Sankaranarayanan, G. (with S. Sivaraman). The $M/Mb/1$ queue with varying arrival and service rates (communicated).

Sankaranarayanan, G. (with R. Nadarajan). General bulk service rule with Erlang Input (communicated).

Sankaranarayanan, G. (with R. Nadarajan and A. Subramanian). A general bulk service queueing system with servers vacation (communicated).

Sankaranarayanan, G. (with R. Sathyamoorthy). On a renewal theorem for a strictly stationary seq. of random variables. To appear in Trans. of ISPQR, Calcutta.

Sankaranarayanan, G. Renewal Theory and its extension for dependent random variables. To appear in Trans. of ISPQR, Calcutta.

Sankaranarayanan, G. (with R. Ramanarayanan and K. Usha). Availability of a 2 unit parallel system.

Sankaranarayanan, G. (with K. Usha). 2-unit standby system and alertness of the worker IEEE Trans. On Reliability. Accepted for publication.

Sankaranarayanan, G. (with R. Ramanarayanan). Reliability and availability of 1-out-of k: G cold standby system with arbitrary failure rate and constant repair time. Accepted for publication in Statistiche Hefte.

Sankaranarayanan, G. (with S. Sivaraman and R. Nadarajan). Markovian Tandem queue with General Bulk Service in Unit II. Communicated.

Sankaranarayanan, G. (with R. Ramanarayanan and K. Usha). The single server queue with Erlang, input and Semi-Markov service times. Zastosowania, Matematyki, 1984.

Savage, Richard, I. Cost-benefit analysis of Demographic data. Proc. Conference on directions for Mathematical Statistics *Spl. Supplement Adv. Appl. Prob.* 62–71, 1974.

Shahani, A.K. and D.M. Crease. Towards Models of screening for early detection of disease. *J. Adv. Appl. Prob.* 9: 665–680, 1977.

Shaw, E.A.G. and N. Olson. Theory of steady state-urban noise for an ideal homogeneous city. *J. Acoust Soc. Amer.* 51: 1781–1793, 1972.

Siskind, V. A solution of the general stochastic epidemics. *Biometrika* 52: 613–616, 1965.

Sutton, G.R. A stochastic model of Acoustic wave propagation through the ocean. *J. Adva. Appl. Prob.* 11: 306–307, 1979.

Weiss, G.H. On the spread of epidemic by carriers. *Biometrics* 21: 481–490, 1965.

Weiss, G.H. On the noise generated by a stream of vehicles. *Transport. Res.* 4: 229–233, 1970.

Weiss, G.H. The shot noise representation for noise for a free traffic stream. *J. Adv. Appl. Prob.* 224–225, 1976.

Vere Jones, D. Space time correlations for microearthquakes—A pilot study. J. Spatial Patterns and Processes. *Adv. Appl. Prob.* 73–87, 1977.

William, S.T. An algebraic proof of the threshold theorem for the general stochastic epidemics. *Adv. Appl. Prob.* 3, 223, 1971.

Wright, S. Evolution in Mendelian population. *Genetics.* 16: 97–159, 1931.

Whittle, P. and L. Pauling. The outcome of a stochastic epidemic—a note on Bailey's paper. *Biometrika* 42: 116–122, 1955.

Zuckerkandl, E. and L. Pauling. *Evolutionary divergence and convergence in proteins, Evolving Genes and Proteins*, eds. V. Bryson and H.J. Vogel. Academic Press, New York, 1965.

III

PHYSICAL AND CHEMICAL SCIENCES

features. These structural phase transitions fall under a category where a regular lattice is distorted slightly "without in any other way disrupting the linkage of the network". Such transitions can occur as a result of small displacements on the one hand or by the ordering of atoms or molecules among equivalent positions on the other hand.

$BaTiO_3$ was classified under the *displasive* type and Slater's theory classified KH_2PO_4 under the order-disorder type using the hydrogen bonds present but it could not explain the deuteration effect. An analysis of the available data by P. Kumara Acharya indicated that many of the hydrogen bonded ferroelectrics could be classified into three categories based on the effect of deuteration on T_c and spontaneous polarization. Raman and infrared spectroscopic studies by R.K. Khanna, P. Kumara Acharya, G.M. Venkatesh, A.V.R. Warrier and others showed that there is no systematic relationship between the type of potential and the hydrogen bond length and the symmetry of the proton potential because the ferroelectric behaviour was influenced by the environment of the donor and acceptor atoms. Subsequently a very large number of ferroelectrics were discovered among the Langbeinite family, Dicalcium strontium propionate family, tetramethyl ammonium tetrazincate family, alkali double sulphates like $A^+B^+SO_4$ (A, B; NH_4, Li, K, Na, Cs and Rb), $NaVO_3$ where the triggering mechanism seemed to arise from nonspherical radicals or molecules like distorted $(NH_4)^+$, SO_4^{2-}, propionate radical etc. giving rise to an order-disorder transition polarizing the rest of the crystal. At this stage it is appropriate to briefly mention the theoretical developments. While thermodynamic treatments and Landau's theory of phase transitions of the second kind have always been helpful, a significant concept was added in 1960 by Cochran and Anderson that a "soft mode" of the crystal decreases in frequency as one approaches the transition temperature from above and as a consequence the polarization appears below the transition temperature. Subsequent attempts to study in detail structural phase transitions and the soft modes have shown that a variety of influences, short range forces ($SrTiO_3$) dipolar ferroelectric ($BaTiO_3$, KH_2PO_4) ferroelastic ($LiCsSO_4$) Jahn Teller, ion, charge density wave etc. play a role and that in many ferroelectrics, the true order parameter is not the spontaneous polarization P_s but is some other quantity. Such ferroelectrics, which are 'Improper' in the sense that the ordering parameter is some quantity other than P_s do not show a Curie Weiss law behaviour in the low frequency dielectric constant or a large increase in the dielectric constant as one approaches Tc and this makes them very good candidates for pyroelectric applications. In addition, if we denote the unit cell volumes by Z^h and Z^l above and below the transition respectively then $Z^l=nZ^h$ then $n=1$ and $n=2r$ (r integer) were termed ferrodistortive and antiferrodistortive. If n is an irrational number the transitions are called incommensurate and some of the recent studies in structural phases transitions are aimed at understanding such incommensurate phases.

Another line of study which is useful in studying structural phase transition is through their thermal expansion anisotropy. S. Devanarayanan, H.V. Tiwary and D.P. Sharma have made some interesting observations with regard to the thermal expansion anisotropy of especially 'improper' ferroelectrics. Devanarayanan investigated $LiN_2H_5SO_4$, methyl ammonium aluminium alum, methyl ammonium chrome alum and sodium trihydrogen selenite $[NaH_3 (SeO_3)_2]$ and using Mohr's circle construction tried to correlate the thermal expansion and the known change in crystal structure. He pointed out for the first time that in most ferroelectrics (except sodium nitrite) the thermal expansion is negative at the Curie point in a direction along which the dielectric anomaly is found. Using the same Fizeou's interferometric technique, Tiwary studied the members of the dicalcium strontium propionate family and confirmed the morphic effect found earlier by J. Kobayashi by X-ray methods.

D.P. Sharma investigating $LiNH_4SO_4$ (space group $Pc2_1n$) by the same optical interferometric technique found thermal expansion anomalies along all the three orthorhomic axes at both its transition temperatures. In this crystal he found that various parts of thermal expansion curves in all the three directions could be explained by using Megaw's tilt concept. From a knowledge of the spontaneous strain and its nonlinear dependence on the square of the spontaneous polarization and the signs and magnitudes of electrostrictive constants he concluded that it is an improper ferroelectric and that the triggering mechanism may be due to the $(NH_4)^+$ ions controlling the interpolyhedral angle. $LiKSO_4$ which belongs to the same family was also studied by him and he found a new transition at about −90°C and B.R. Madhu later confirmed it by careful dielectric studies. It is only much later that Sanji Fujimoto, Yasuda, Hibino and Narayanan confirmed that it is a ferroelectric. A.M. Shaikh and M.A. Viswamitra studied the thermal expansion of $NaVO_3$ by X-ray method and found anomalies confirming the ferroelectric behaviour.

Almost all these, crystals of the different families mentioned above were studied by conventional Raman and infrared spectroscopy and from 1980 laser Raman spectroscopy by H.L. Bhat, C.K. Subramanian, V. Srinivasan, P. Chandrasekhar, B. Raghunatha Chary and S. Seetharaman in different orientations and at different temperatures. The spectral features and the changes induced by change of symmetry during structural phase transition have helped us understanding why only some members in any family of compounds are ferroelectric. For example a recent study by V. Srinivasan and C.K. Subramanian of the Raman spectra of mixed crystals of $[(NH)_{1-x} K_x]_2 SO_4$ at various temperatures and relative proportions of K^+ ion and $(NH_4)^+$ ion, up to 50 per cent have shown that the frequency of the totally symmetric vibrations of SO_4 and NH_4 ions increase and thereafter the frequency of the SO_4 vibrations decreases and attains the value found in

K_2SO_4. This variation in frequency up to 50 per cent of potassium concentration is due to the breaking of the hydrogen bonds of the type N—H—O in one of the nonequivalent sets of $(NH_4)^+$ groups. The behaviour of Raman intensities of A_9 (v_1) mode of SO_4^{2-} for various concentrations of K ($x=0$, 0.3, 0.11, 0.5 and 0.85) suggest that the phase transition changes from first order type to one of second order. The phase transition in mixed crystals of $[(NH_4)_{1-x}K_x]$ SO_4 can be a cooperative phenomenon arising from a coupling between $(NH_4)^+$ ions with the distorted SO_4^{2-} ions in the low temperature phase.

Interestingly $LiRbSO_4$ and $LiCsSO_4$ which are also members of the same family show a different behaviour. Sanji Fujimoto and co-workers showed that $LiKSO_4$ exhibits P-E hysteresis loops along the C axis of $LiKSO_4$ not only in the phase between −25° and −70°C but also below −70°. $LiRbSO_4$ reveals not only ferroelectricity but several successive phase transitions. $LiCsSO_4$ is however ferroelastic. A Laser Raman spectroscopic study of $LiRbSO_4$ and $LiCsSO_4$ has therefore been made and the analysis of the integrated intensities and polarizations and linewidths as a function of temperature have also been made by Raghunatha Chary.

It is well known that the pressure effect on the dielectric behaviour of ferroelectrics is valuable in understanding the nature of the transition. Thanks to a collaborative programme with Prof. Sanji Fujimoto, N. Yasuda and K. Takagi of Gifu University of Japan supported by JSPS, the dielectric measurement of ferroelectric trissarcosine calcium chloride (TSCC) was made under various pressures up to 6K bar. A striking decrease in the peak value of the permittivity ε at the transition temperature T_c was observed with increasing pressure. The value of T_c increases linearly with a pressure coefficient $dT_c/_{dp}=$ 11.1 K k bar^{-1} at low pressures. This increase in T_c supports the suggestion that the ferroelectric transition is of the order-disorder type and with the application of pressure the transition changes from second order to first order. Recently a piston-cylinder type of high pressure cell has been built by Raghunatha Chary and dielectric measurements under hydrostatic pressure upto 7.4 k bars were made on $LiCsSO_4$. It is observed that the transition temperature decreased with increase in pressure. The experimentally observed $dT_c/_{dp}=-1.25$°K k bar^{-1} and is in better agreement with the theoretical value from Ehrenfest relation ($\simeq 1.0 \pm 0.5$°K k bar^{-1}) than an earlier measurement by others.

The characteristic property which distinguishes a ferroelectric is its macroscopic polarization which can be switched or reoriented by the application of an appropriate external field. However the coercive field is not well defined and the mechanism of polarization reversal and domain dynamics in ferroelectrics show a complexity that make it difficult to generalize and draw a common rule for all types of ferroelectrics. Radiation damage, internal biasing fields, ageing and defects, affect the switching characteristics. Hence the switching processes and radiation damage effects were studied by Ramnath Ravi and K.S. Sangunni in TGS, TGSe, sodium nitrite and dicalcium strontium propinate. These have helped us understand better the field dependence. Since ferroelectric materials find use as ceramics, the effect of particle size on the dielectric behaviour of some of these crystals was investigated by A.H. Rama Rao and M.R. Srinivasan.

Part II

'Remote Sensing' is an easily understood word and it encompasses all methods that allow us to detect and to analyse quantitatively a volume of air in the atmosphere at a distance from the instrument. The optical methods to which my remarks will be confined makes use of the optical properties of matter like their optical absorption, emission and scattering. In the microwave region one makes use of the rotational transitions and are applicable for molecules of ozone, water vapour and carbon monoxide. In the near infrared and infrared region ranging from 1 to 5 μm vibration—rotation spectra exist for most of the atmospheric pollutants. Because of water vapour and carbon dioxide absorption the atmospheric transmission is good only within some 'windows', around 1 μm, from 3 to 5 μm and 9 to 13 μm. In the visible region from 0.35 to 8 μm electronic transition spectra correspond to broad absorption bands. Practically only NO_2 can be detected in this spectral region. In the ultraviolet between 0.25 and 0.30 μm quasiperiodic absorption spectra with bands of a few nanometers are observed for SO_2 and ozone with maxima and minima of absorption.

Remote sensing can be done using a natural source, in which case the sensor is called a 'passive sensor' and generally instrumentation with a passive sensor is simpler, light and robust enough to be flown or carried in moving platforms. Generally they measure the total quantity of the species present over the entire path and it is not easy to calculate the variations of concentrations with height. To this category belong radiometers, spectrometers, interferometers and Fourier transform analysis, and Laser heterodyne amplification of spectral lines. A Michelson interferometer system using fourier transform analysis mounted in a van can be used to analyse the emissions from stacks and chimneys and the main advantage of such a system is that it is possible to carry out a complete analysis of the pollutants in the plume. A version of this instrument called ROSE (remote optical sensing of emissions) can be used as a light source for monitoring low temperature emissions around factories. In the Aeronautical Development Establishment, Bangalore, M.R. Seshadri has successfully built a rapid scan fourier transform spectrometer for Mid-IR (3 to 5.5 μm) and applied it to study the grey body continuum from a hot engine, and the exhaust gases.

On the other hand a considerable amount of effort has been spent by U.S.A., European Joint Campaigns and by Japan in developing active sensors characterized by the use of a light source which is often an intense laser and a detector to analyse the spectra. The use of the laser offers many advantages arising from its directionality, power density and narrow spectrum but suffers from drawbacks like limited life of the laser, high cost and maintenance etc. To this class of sensors belong the Laser absorption spectrometers, monowavelength, Differential, Raman and fluorescence LIDARS.

The choice of any particular remote sensing technique for the study of atmospheric pollution depends on the purposes for which it is made. Today remote sensors are able to overcome difficulties spatial and temporal variations in the atmosphere up to 30 km from the location of the instrument. However the collection of concentration values as a function of height and time can be interpreted and utilized only if at the same time meteorological data like temperature and humidity in the air, wind direction and speed, barometric pressure which change quickly with place and time are known. In general cost of laser and optical remote sensors is at present higher than point monitors and also calls for a close collaboration between meteorologists, physicists and electronic and optical scientists. It is needless for me to say that atmospheric pollution research is an important topic and an integral part of environment programme. While the laser based systems can be expensive at the moment, the forecasts by the leading works in this field is that the use of these systems can be made cost effective and the costs will be reduced as the technology develops.

Acknowledgement

I thank the Mysore Sales International Limited, Bangalore for their support to me through Endowment Professorship at the I.I.Sc.

Note

As much of the work covered in Part I have been published and the list of references will be long, I have taken the liberty of giving only some key references for part II to help scientists who wish to take up work in this important area.

REFERENCES

The turning point: Science, society and the rising Culture, Fritjof Capra Simon and Schuster U.S.A. 1982. Also available in Fontana paperbacks 1984.

Instrumentation for environmental Studies lecture Notes of Workshop sponsored by Environmental Studies Programme. Instrumentation and Services Unit, IISc, 1984, Coordinator T.S. Radha.

Pollution: Engineering and Scientific solutions, Proceedings of the first International meeting of the Society of Engineering Service held in Tel Aviv, Israel 1972. Ed. by E.S. Barrekette, Plenum Press, 1973.

Laser Monitoring of atmosphere, Ed. E.D. Hinkley, Topic in Applied Physics, Vol. 14, Springer-Verlag, Berlin, 1976.

Optical and Laser Remote Sensing, Springer Verlag Series in Optical Sciences 1983. Ed. D.K. Killinger and A. Mooradian.

Laser microprobe mass analysis (LAMMA) as a tool for particle characterization, A Study of coal fly ash. Erie Deneyer et al., *Environment Sci. Technology* 1983, 17: 457.

NASA Multi-purpose Airborne DIAL system and measurements of Ozone and Aerosol Profiles. E.V. Browell et al. *Applied Optics.* 1983, 22: 522.

Tunable diode laser systems for measuring trace gases in tropospheric air. H.I. Schiff et al. *Environ. Sci. Techno.* 1983, 17: No. 8, 352.

A survey of Laser and Selected optical systems for remote measurement of pollutant gas concentrations. William B. Grant and R.T. Menzies, Air Pollution Control Association, March 1983, Vol. 33.

Optical methods of remote sensing of atmospheric pollution. P. Guillot, *Spectrocim. Acta.* 1983, 38B: No. 11/12, p. 1457.

Proceedings of the Symposium on infrared technology and Instrumentation organized by Electronics and Instrumentation Committee, Department of Atomic Energy. March 1980.

6

Chemistry in the Solution of Environment Pollution

M.M. Taqui Khan

The chemical aspects of environmental pollution and their remedial measures mostly in reference to the build up of the concentration of toxic metals and compounds in the environment are discussed in this paper. The environmental effect of chemical compounds can be considered to be a disturbance in the ecosystem in terms of an increase in the concentration of metal ions and organic compounds beyond their natural levels in plant and animal life as well as in air, water, soil and sediments (Holdgate, 1983; Robinson, 1984). There are three general routes by which man has disturbed the natural balance through pollution:

1) By the introduction of abnormal anions of metal ion and metal complexes of toxic elements like mercury, lead and cadmium in one or more parts of the ecosystem which will be referred to as the bio-inorganic aspects of pollution.

2) By the introduction of synthetic organic compounds like pesticides, toxic effluents or abnormal level of natural organic compounds in the system, referred to in this paper as the bio-organic aspect of pollution.

3) By the introduction of toxic gases like oxides of sulphur, nitrogen and carbon and particulate matter in the atmosphere.

Considering the bio-inorganic aspect of pollution, metal ions can be classified into essential and toxic based on their biological requirement (Table 1). Even an essential element like copper required in trace quantities for various metobolic processes can become toxic in concentrations exceeding the biological limits. The toxic elements like Hg, Cd, Pb, Pd, Pt, Sn, Sb, As and Ge find their way through complexing with suitable organic molecules into the geosphere, to fresh and marine water and to plants and animals. These are referred to as accessible metal ions. Other heavy elements mostly from Group III and IV of the periodic table gets extensively hydrolysed and become inaccessible. The pollution problem is thus restricted to accessible metal ions where their limit in the geosphere especially in water has to be controlled in order to prevent several physiological disorders. Some of these toxic elements may be air borne and get deposited on the particulate system to be carried in the lungs. Particulate control of environmental pollution has become a very important aspect of pollution control.

TABLE 1
Toxicities of metals

Toxic and accessible to biosystems			Toxic but not accessible to biosystems		Non-toxic	
Be	As	Ag	Ti	Rh	Li	Al
Co	Sb	Hg	Hf	Ir	Na	Fe
Ni	Bi	Au	Zr	Os	K	Si
Cu	Se	Pd	W	Rh	Rh	
Zn	Te	Pt	Nb	Ba	Ca	
Cd	Sn		Ta	Ga	Sr	
	Pb		Re	La	Mg	
	Ge			Lanthanides		

The bio-inorganic aspects of pollution deals with the disturbances in the limits of natural organic compounds in the geosphere. Increases in the concentration level of organic molecules in the sea disturb the sea ecosystem and cause havoc with marine life. The geosphere is also rich in natural organic molecules like humic and fulvic acids, proteins and carbohydrates which keep up the balance of micronutrients in the soil. Intake of unnatural organic molecules like pesticides, phenolic compounds, bio-nondegradable detergents the geosphere upsets the level of natural ligands and in turn effects the delicate equilibrium with metal ions. The bio-organic control of pollution deals with a check in the entry level of these unnatural organic molecules in the ecosystem or find out ways and means to destroy or degrade them into safer products by chemical methods.

MOBILITY OF TOXIC METAL IONS

Mercury

Alkylmercury compounds were used (Martell, 1975) in agriculture as seed preservatives for almost 50 years when it was realized in the late sixties that these compounds increase the pollution levels of lakes and streams to a dangerous limit of >0.5–1.0 ppm. The chlor-alkali industry with mercury cells is the main culprit in mercury pollution since the amount of mercury lost in the process is primarily mobilized to the environment. The new membrane cell for the chlor-alkali industry has taken care of the problem but the higher level of mercury sediments at the bottom of lakes will continue to pollute the air and rivers and will manifest their effect on aquatic life for years to come. Poisoning due to metal and its vapours arise from two sources: (DHSS Hg, 1977) direct absorption of the metal through skin and inhalation of vapour. The currently accepted maximum safe environmental concentration (Moore and Timbs, 1984) of Hg vapour is 50 μgM^{-3}. The rate of evaporation of Hg from a clear surface is 8×10^5 μg Me^{-2} h^{-1} at room temperature and increases rapidly as the temperature rises. For this reason, it is important to cover all exposed Hg surfaces and keep the temperature of the laboratory as low as possible. Transport of mercury to man usually occurs by absorption of methyl mercury by fish which are then consumed as food. There are now legislations to stop fishing in mercury polluted lakes. Certain bacteria can reduce methyl mercury to elemental mercury which can be volatalized in atmosphere and be less toxic. Other toxic metal ions like tin, palladium, platinum, gold and iridium that can form stable metal alkyl bonds in solution are also sources of dangerous pollution in lakes and rivers.

Lead

The 1968 census of lead pollution in the U.S.A. indicated that 98 per cent of the 400 million pounds of lead released to the atmosphere was from gasoline exhaust. The other minor sources are coal combustion and lead smelting. Most of the lead present in the atmosphere is in the form of aerosols and particulate matter with a residual time of seven to 30 days depending on rainfall and atmospheric conditions. The air borne lead is in the form of insoluble particulate matter and the bulk of it is retained in the soil and sediments with very little present in water in soluble form. Thus there is no fear of water contamination by lead. There is also no evidence of lead absorption in the system through lungs since the particulate matter stays in the lungs for a long time. About 95 per cent of the lead in the body is stored in bones and is generally inert. In the case of acute lead poisoning it is transferred to soft tissues and is measured as blood lead. Transport of lead by living organisms is not clearly understood. Very little soil lead is taken up by plants and there is no tendency to transfer to other animals or recycle the lead. The major victims of lead poisoning are industrial workers, who come in contact with appreciable lead and the urban population that is exposed to dust and particulate matter of high lead content. The use of lead-free gasoline and the incorporation of exhaust filters have taken care of the lead pollution to a great extent in developed countries. Elf Aquitaine the French Oil giant has plans to spend $106.6 million adapting its refinery system to the production of lead-free petrol. The change over will cost the company about 300 million French Franks per year. Lead-free petrol production is also planned by the Saudis in joint venture with the French and Italians to manufacture the anti-knock additives methyl-tertiarybutyl ether (MTBE) to the tune of 550 tonnes per annum by 1988. Wet scrubbers and electrostatic precipitators used in chimneys and other installations can take care of toxic particulate in the atmosphere. The permissible limits of lead in drinking water is 50 g dm^{-1}. Lead in drinking water can be decreased by avoiding lead pipes or by keeping the pH at ~8–8.5 where lead is extensively hydrolyzed.

Cadmium

It has been estimated that about 5×10^6 pounds of cadmium are released (Martell, 1975) each year in the U.S.A. into the air, water and soils. The source of cadmium pollution in urban areas are metallurgical plants, cadmium plating and battery fabricators. The transport of cadmium in the geosphere is similar to lead. Smokers get a much larger dose of cadmium than non-smokers.

As, Se, Sn, Te, Ti, Sb and Ge

The role of these elements in the biocycle is yet unknown. They are all known (Lewis, Froelich and Andreac, 1985) to form organometals in the biosphere by biomethylation by bacteria, fungi and algae. Naturally occurring methylated species have been reported (Lewis, Froelich and Andreac, 1985) in estuaries and sea water for Sb, As, Ge and Sn. With the exception of Sb, As and Ge there is no constant profile of methyl metal compounds to judge their biochemical behaviour. Monomethyl and dimethylgermanium are reported (Lewis, Froelich and Andreac, 1985) in river waters, estuaries and sea water. These organogermanes are very stable towards oxidation and U.V. irradiation. The residual time of these compounds in oceans is estimated to be several thousand years. The role of these compounds in the natural ecocycle of water is yet unknown.

Toxicity versus Essentiality of Metal Ions

It is important to understand the essential role of metal ions in biological systems before one talks about their toxicity. The biological selection of chemical elements is based more on their evolutionary chemistry (Williams, 1981, 1983) rather than their natural abundance. Only those elements with highly effective chemistry evolved through ages of evolution are involved in biology. Unlike the chemical reactions performed in a laboratory Nature has achieved the selection of elements through processes of evolution and adaptation. It is difficult for Nature to change the structure of the atom in biology but it can certainly place it in an appropriate environment for its effective use.

The natural selection of elements in biology depends (Williams, 1981) on the nature of the species, the cells in the species and among the organneles of a given cell. The selective combination of a given element with an organic molecule is achieved by the designed synthesis of the organic molecule itself from the non-metals, C, N, O, F, Si, P, S, Cl that can form covalent bonds. The chemical elements can then be divided into functional biological **'traps'** depending on their utilization and best function (Williams, 1983). As stated earlier, in the bio-utilization of elements abundance has not been the primary factor, their selection depends on chemical factors such as the pH, the redox potential, the solubility product, the effective complexation constant of the metal ions, the nature of the complexes (covalent verses ionic) and the specificity of binding to the substrate molecule.

The metallic elements in biology can be classified into three groups. The elements of group IA, DIIA, like Na^+, K^+, Ca^{2+}, Mg^{2+} and sometimes Mn^{2+} form very weak complexes with organic ligands and are available as free ions. Their movement in a cell is restricted by a membrane trap and is controlled by energized transport across the membrane. The anions, Cl^-, SO_4^{2-} and HPO_4^{2-} also behave in a similar manner. These ions are used in the transport of charge and electrical impulses across the cell.

Transition elements Mo, Cu, Zn, Ni, Co, Fe, mostly in their divalent form are complexed by small and big organic molecules to form either thermodynamically stable (thermodynamic trap) or thermodynamically unstable but kinetically stable bonds (kinetic trap). Irrespective of the nature of the ligand, the stability of the metal complexes of these ions increase in the order $V < Cr < Mn < Fe < Co < Ni < Cu > Zn$; usually referred to as the Irwing-William order of stability. These ions form mobile complexes with small organic molecules like iron in siderins or they can form complexes with large rigid ligand structures like porphyrins. Specificity of binding in these molecules is achieved by steric (conformation, size of the metal ion) and chemical (pH, redox potentials) constrains. Large molecules like proteins can also bind metal ions to form thermodynamically stable or kinetically stable complexes. The transition metal ions that are usually referred to as **'trace elements'** take part in redox and acid base reactions. Some of the well known examples are cytochromes and ferridoxins that are electron transport enzymes and peptidases that are acid base catalysts. Whereas the former are Fe^{3+} complexes, the latter enzymes use Zn^{2+} at the active site. These transition metal ions are not available as free ions in biology since they are extensively hydrolyzed at the biological pH. Some of the ions like H^+ can freely move between the ionic state and the kinetic traps. Metal ions like Mn^{4+}, Fe^{3+}, Cr^{3+} and Al^{3+} are less available in biological systems as compared to their natural abundance since they are extensively hydrolyzed and form precipitates. Similarly Si^{3+} also form precipitates. There are also elements like Rh, Cs, Sr, Ba, W, Cd, Au, Hg, Pb, Ag, Ba that may be possibly required in some cases but are essentially toxic (Table 2).

TABLE 2

Major (essential) and minor (trace) elements

Essential Elements: (Membrane Trap)	**H, Na, Ca, Mg, C, N, O, P, S, Cl**
Trace Elements: (Thermodynamic & kinetic traps)	**V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, I**
Possibly required: but otherwise toxic.	**Rh, Cs, Sr, Ba, W, Cd, Au, Hg, Pb, Ag**

The toxicity of chemical elements is concerned with the disturbance in the natural function of the elements, cations and anions as discussed above. Change in the nature of the organic molecule to a species with a higher affinity for a certain metal ions can remove these essential elements from the biological site. This cyrptands are skin contact poisons since they can very effectively remove Na^+ and K^+ by complexation. CO and CN^- can impair the oxygen carrying capacity of haemoglobin by blocking the oxygen coordinating site. The presence of a transition element in a higher concentration then warranted by its biological activity or the presence of a transition element that can effectively compete for an essential biological ligand can disturb the fine kinetic and thermodynamic balance in the cell and lead to catastrophic reactions. Essential trace elements like Cu^{2+} and Fe^{3+} can become toxic when present in large quantities in Wilsons disease and Coolie anaemia respectively. Thus there is a fine natural balance between essentiality and toxicity in biological systems which can be upset by environmental pollution. The effects of deficiency and toxicity of some of the common trace elements is shown in Table 3.

Water Pollution

Water pollution constitutes one of the most hazardous forms (Chem. and Ind. News, 1985) of pollution, since polluted water effects the natural ecosystem of lakes and rivers and effects plants and animal life. Every major river in India (Chem. and Ind. News, 1985) is polluted due to biodigestable garbage dumping, channelling of sewage and industrial effluents. Our rivers are contaminated with heavy metal ions like mercury, cadmium, lead and chromium. The industrial effluent in some of the rivers in Gujarat like Mahi Sagar is reported to have destroyed not only marine life but has not spared even cattle. The Ganga cleaning project promoted by the Prime Minister is an important step in the combat of water pollution and should be extended to other rivers.

TABLE 3

Effect of deficiency and toxicity of trace metals

Metal	Deficiency symptoms	Toxicity
Fe	Anaemia	Coolies anaemia haemochromatosis
Cu	Anaemia, ruptene of blood vessels	Wilson's disease, injury to liver, kidney
Mn	Impaired growth skeletal abnormalities	Nerve damage
Zn	Impaired growth, taste, seneral development	Poisoning symptoms
Co	Anaemia, required for vitamin B_{12}	Polycythaemia
Mo	Enzyme function	Teart in cattle
Se	Liver necrosis reduced glucose tolerance	Alkali disease. Blind slaggers in livestock
Cr	Glucose tolerance adversely effected	General poisoning
Sn	Poor growth, defective teeth	"
Ni	Adverse effect in chicken	"
V	Depression of growth rate and lipid oxidation	"
Si	Effect growth	Urinary calculi
Ca	Effect bones	"
I	Goiter	Not yet found
Pb	Influence growth	Brain, kidney and liver damage

Water Distribution

Of the total water resources of the world only 0.05 per cent is held on land and atmosphere, the rest being as ice caps and glaciers and the ocean as salty water functioning as a reservoir in nature's hydrological cycle. Nearly 0.01 per cent of the total water is in saline lakes and inland seas. An estimate of the distribution of the world's water supply based on the U.S. Geological Survey is presented in Table 4.

The annual rainfall on land area is 1 to 1.5 m/year but the fresh water and saline water distribution on land is uneven. Good quality water being an essential raw material, exploitation of the agricultural and mineral wealth of vast areas of the world is in many cases inhibited by the lack of fresh water supplies. In many of these areas, there is immense accumulation of natural water, which due to the dissolved salt content, cannot be utilized. A general term for these waters is 'brackish', which adjective, in general, is applied to water containing in solution excess quantities of common salt (sodium chloride) together with lesser amounts of other salts.

The tolerance of human beings to salt in drinking water varies, but in general it may be said that a sodium chloride content of 500 ppm is acceptable and has been set as a limit by the World Health Organisation. In tropical

TABLE 4

World's water supply based on U.S. geological survey estimates

Location	Water volume (cu km)	Percentage of total water
Fresh water lakes	120,000	0.009
Saline lakes and in land seas	100,000	0.008
Average in rivers and streams	1,200	0.0001
Soil moisture and near surface ground water	64,000	0.005
Deeper ground water	8,000,000	0.61
Ice caps and glaciers	28,000,000	2.15
Atmosphere	12,400	0.001
Oceans	1268,000,000	97.2

regions, where much salt is lost in the form of human system perspiration, a higher limit of 1000 ppm can be accepted. Even within these limits the water should not contain more than 5 ppm of fluoride and less than 100 ppm of nitrate (Roy, 1968). The nitrate level in water under arable lands, fertilizer complexes rises to limits much higher than the tolerable limit. There are controversial reports of the correlation between the nitrate intake and gastric cancer (Forman, 1983). The Imperial Cancer Research Fund, Oxford, has found that there is no direct correlation (Nature, 1985) between high nitrate/nitrite exposure and an increased risk of stomach cancer. According to another finding there may be a link between the risk of cancer and the intake of nitrate when the latter is very high. There is however, an ecological advantage of nitrate bearing water to coastal marine environment (Capone and Bantista, 1985).

The phenomenon of acid rains especially in the northern hemisphere is associated with rain water of pH 3.5 to 4.5 due to dissolved NO_2 and SO_2. The effect of acid rain (Howells and Kallend, 1984) on the terrestrial and marine ecosystem is controversial and is the subject matter of many conflicting reports. While acid rain is reported to have devastating effect in terrestrial forests, it is stated to enhance the marine primary production (Paeri, 1985) especially phytoplankton by nitrogen enriched acid rain.

The problem of nitrate in ground water and acid rain more than exemplify the fact that there is a complex correlation in the terrestrial and marine ecosystems and the problem has to be looked at in the totality of the picture rather than on an isolated basis.

Brackish Water Problem in India

It has been estimated that India has a usable water potential of 9.35×10^{12} cu m as a result of annual monsoon rainfall. Of this, 2.65×10 cu m is ground water potential. These figures are indicative that there is enough water to meet the requirements of people for agriculture and for drinking and other day to day needs. However, due to the vastness of the country and the topography and scattered intensity of the rainfall pattern, the problem of finding and reaching good quality water to the consumer is a colossal one, particularly in areas which are arid. The available resources in such areas are mostly saline or brackish and very often contain fluorides to a highly objectionable level. The most extensive semi-arid and arid regions are in the central Deccan Plateau and north western parts of India where drinking water problems due to salinity are acute.

Desalination Processes

Processes for obtaining water from saline sources are mainly grouped under two heads: (1) processes involving a phase change such as evaporation and freezing where water is removed from salt, and (2) processes involving no phase change but utilizing the properties of membranes as in electrodialysis hyperfiltration or reverse osmosis. The Central Salt and Marine Chemicals Research Institute is active on three processes for desalination: solar distillation, reverse osmosis and electrodialysis.

Composition of Sea Water

In sea water the important ligands are chloride, sulphate and carbonate and to lesser extent bromide, borate and fluoride (Table 5). The pH of natural sea water is 7.8 and specific gravity at 20°, is 1.0243 g/cc. Thus one can consider the OH^- ions to be present in appreciable quantity in sea water. The composition of sea water is fairly constant all over the world with approxi-

TABLE 5

Major metal ions and ligands in sea water (Riley and Chester, 1971)

Major constituents	Concentration mg/kg sea water
Chloride	19,353 (0.55)
Sodium	10,760 (0.47)
Sulphate	2,712 (0.028)
Magnesium	1,294 (0.054)
Calcium	413 (0.010)
Potassium	387 (0.010)
Bicarbonate	142 (0.0023)
Bromide	67 (0.00083)
Boron (H_3BO_3)	4 (0.00043)
Fluoride	1 (0.00007)

Note: Figures in parentheses are in terms of molarity.

mately 3.5 per cent dissolved solids. Besides the major ions and ligand shows in Table 5, sea water contains about 29 elements in tracer quantities as shown in Table 6.

TABLE 6

Important trace elements in sea water

Elements	Concentration in Mg/L
Lithium	180
Beryllium	6×10^{-7}
Boron	4.5
Carbon	28
Fluorine	1.4
Phosphorus	7×10^{-2}
Scandium	1.5×10^{-5}
Titanium	1×10^{-3}
Vanadium	1.5×10^{-3}
*Chromium	6×10^{-4}
*Manganese	2×10^{-3}
*Iron	3×10^{-3}
*Cobalt	8×10^{-5}
Nickel	2×10^{-3}
*Copper	3×10^{-3}
Zinc	5×10^{-3}
Arsenic	2.3×10^{-3}
Rubidium	12×10^{-2}
Strontium	8.5
Molybdenum	1×10^{-2}
Ruthenium	7×10^{-7}
Silver	1×10^{-4}
Cesium	5×10^{-4}
*Barium	30
*Gold	5×10^{-6}
Mercury	5×10^{-5}
Lead	3×10^{-5}
Bismuth	2×10^{-5}
Uranium	3.3×10^{-3}

*Considerable variation.

Sea water contains only small amounts of organic compounds, such as humic acids and amino acids which are capable of forming weak chelate complexes with trace metals at pH 8. Although present in relatively small concentrations, organic ligands may be one of the controlling factors in metal transport, in absorption on suspended and bottom sediments and in the formation of polymetallic modules. The small quantity of boron (0.1 per cent) present in sea water is complexed by the dissolved carbohydrates. Ferric ion, which forms strong complexes with chelating agents, is present in a chelated form in an ecologically insignificant proportion.

The dissolved inorganic ions present in sea water are principally electrolytes although uncharged species such as H_3BO_3 and dissolved gases are included in this category, together with micelles. Competitive complexing with major anions (Cl^-, OH^-, HCO_3^-, SO_4^{2-}, F^- and perhaps organic ligands) is the principal factor controlling the nature of the inorganic species present in sea water. The interaction between the cations and anions may range from purely electrostatistic attraction, found in ion-pair aggregates in a medium of ionic strength of 0.8 to covalently bound species formed between the cations and donor chelates (ligands). The actual equilibrium between ion pairs, aggregates and chelate is highly complicated. All these complex species will exist in solvated forms in which the hydration may range from simple ion-dipole interaction (with the alkali metals) to coordination (for transition metals). Other ions or molecules present in water may compete with water molecules (aquo group) for positions in the coordination sphere of the metal ion. The alkali and alkaline earth metals do not form strong complexes and their tendency even to form ion pairs (such as $NaCO_3^-$. $MgCO_8^-$), is rather limited.

Because of the huge volume of sea water, sea pollution is restricted only to about a small distance from the shore where the marine flora and fauna may be affected by industrial and estuarine effluents.

Air Pollution

One of the impacts of industrialization and the vehicular mode of transport is the increase in the level of effluent gases like CO, CO_2, NO_x, SO_x, hydrocarbons and depletion in the level of ozone in the atmosphere. The contribution from motor vehicles (Chem. and Ind. News, 1985) in lines of NO_x, CO and H—C are about 10 tonnes per year. In most of the cities of India the air pollution (Jalees, 1985) is many times higher than in London, Tokyo, Paris and New York. Bombay emits 1700 tonnes of pollutants daily of which 35 per cent is SO_2. Calcutta discharges approximately 1300 tonnes of pollutants of which 35 per cent is CO. The particulate suspended matter in Delhi is as high as 641–1000 μ gram/cu m, one of the highest levels in the world (Jalees, 1985).

The source of CO_2 is carbonaceous fuels and oxidation of organic matter. Measurement of trapped CO_2 in ice by furnification process (transformation of snow into ice) in Antarctic ice cores from various depths ranging from 89 m to 197 m reveal an increase in the amount of CO_2 from about $+279 \pm 3.0$ parts per million per volume in ca 1734 A.D. to 328 ± 3.5 in 1962 to 345 ppm V in 1984 an increase (Neftel et al., 1985; Raynaud and Barnola, 1985) of 22.5 per cent compared to 1750. Increasing atmospheric CO_2 concentrations are expected to cause substantial changes in climate. The observation data show that the globe has warmed (Wigley and Schdesinger, 1985) by about 0.5° over the past 100 years. These results though uncertain (Folland et al., 1984) at present due to difficulty of separation of noise level of natural interannual and interdecodal temperature fluctuation from that of pure CO_2 warming, nevertheless indicates a significant heating trend. Stringent legislation about the use of wet scrubbers (Daniels, 1984) and Cottrel's electrostatic precipitations (Coleman, 1984) reduce to a great extent the particulate emission and oxides of sulphur and nitrogen. The use of three way catalysts in automobile exhaust in the U.S.A. and Japan since 1970 have significantly reduced the CO_2 and NO_x emission. The effect of these changes on ozone level is still not clear. Improved long path detection of air pollutants by diode lasers (Sharp, 1982) and DIAL (differential absorption lidar) lasers will make it possible to detect oxides of nitrogen and sulphur up to 0.1 ppb and thus enforce strict control on the quality of air.

Bio-organic Aspects of Pollution

The bio-organic aspect of pollution is concerned with the introduction of unnatural organic material like pesticides industrial effluents, organic biodegradable and carcinogenic substances in the geosphere. The toxicity of these substances are related either directly to the interference in the biological processes of plants and animals life or indirectly by disturbing the complexing pattern with metal ions in the geosphere thus perturbing the metal-ligand interaction balance. In some instances ligands like EDTA, NTA etc. that are used in detergents and other products can solubilize the insoluble toxic elements like lead and greatly enhance the chances of water pollution.

Pollution by Pesticides

Pesticides were introduced in India in the fifties to eradicate vector-borne diseases and to raise the agricultural produce. From a beginning of 2000 t/a in the fifties the use of pesticides has grown in India today (Jalees, 1985) to nearly 85,000 t/a. After Japan, India is the largest manufacturer of pesticide. Though pesticides have given us the fruits of the Green Revolution we have paid a heavy dividend in terms of the contamination of the environment with a multitude of deadly and toxic pesticides. Most of the food material like milk, fruits, vegetables, contain a manyfold excess of DDT and dieldrain than the tolerable limits (Jalees, 1985). The contamination of the environment by pesticides is mostly due to the use of indiscriminate and larger quantities of pesticides on farms than is really necessary. The indiscriminate use of pesticides has resulted in severe health problems and the loss of innocent lifes. There are 750,000 cases of pesticides poisoning annually all over the world and about 14,000 deaths of this 72.8 per cent deaths occur in developing countries. Other deadly organic materials are polychlorinated triphenyls (PCB's) and 'agent orange' that was used in the Vietnam War as a defoliant

(Carter et al., 1985). One of the components in 'agent orange' is the deadly 2, 3,7,8-tetrachlorodibenzo-n-dioxin (TCDD). Such compounds leave their deadly impact on the environment for many years. Biochemical degradation of pesticides by oxidative hydrolysis and conjugative reaction with sugar, amino acids and nitrites give rise to carcinogenic organic compounds like nitrosamines. Photodegradation of pesticides by sunlight, air and singlet oxygen also give rise to toxic agents which may remain contaminated with the soil for a long time and may eventually be washed to the rivers.

Unnatural Organic Compounds in the Environment

Introduction of organic compounds into the environment by waste chemicals, effluents or municipal sewage plants carry an immediate threat of the complexing capacity of these ligands or organic compounds with metal ions. These ligands like EDTA or NTA can solubilize (Martell, 1975) (Sequester) insoluble lead or mercury compounds from the silt and release them in the water stream causing danger to fish or entry of these harmful metal ions into the municipal water stream. Both ethylenediaminetetracetic acid (EDTA) and nitrilotriacetic acid (NTA) belong to the group of aminopolycarboxylic acids and have the capacity to complex a wide variety of metal ions with very high stability constants. EDTA is about three times as costly as NTA but on weight to weight basis it offers the advantage of higher stabilities of metal complexes at relatively lower concentrations. About 200 million pounds of organic sequestering agents per year consist of about 75 million pounds of EDTA, 60 million pounds of NTA and 65 million pounds of the other sequestering agents related to EDTA or NTA. The largest use of EDTA is as a speciality cleaning agent, textile applications and liquid fertilizers. Sodium tripolyphosphate (TPP) is used as a builder for detergents as it is inexpensive, forms soluble complexes and is fully biodegradable by simple hydrolysis. Thus the BOD of lakes and rivers is not increased by TPP. The ecological effect of TPP is, however, to increase euphotrism in lakes by the supply of the outrient phosphate. This euphotrism is more acute than the supply of nitrate nutrient in the lakes by natural and biodegradable pathways. This problem is overcome by the use of NTA as a detergent builder. For quite sometime there was a lot of concern in the U.S.A. about the possible hazardous effect of the detergent when released in large quantities to the environment. Detailed studies have subsequently revealed (Martell, 1975) that NTA is fully biodegradable to simple amino acids, NH_3 and CO_2. One of the products of the biodegradation of NTA, aminodiacetic acid does not form carcinogenic nitrosamines but is biodegraded faster than NTA to sarcosine and glycine. The amount of nutrients supplied to water by the biodegradation of NTA is insignificant compared to other nitrogen sources and there is no contamination of tap water by heavy metal ions since NTA is effectively removed by $Fe(OH)_3$. The NTA story is one of the best examples of a thorough environmental study done on an unnatural organic compound. There is a need for similar studies on industrial effluents in order to make our environment safer and cleaner.

Control of pollution in the environment is thus linked up with the scientific, social and economic parameters of a society in a country. The remedial measures to be adopted depend on the degree of awareness of the society towards these problems and the cost-benefit economic ratio in the treatment of industrial effluents, liquids and gases. Even if this ratio is tilted more on the cost aspects the programme of a clean environment has to be implemented in order to pass on a better world to live for our future generations.

REFERENCES

1. Holdgate, M. *Chemistry in Britain* 19: 3, 1983.
2. Martell, A.E. *Pure and Appl. Chem.* 44 (1): 81–113, 1975.
3. Robinson, A. *Chemistry in Britain* 20: 34, 1984.
4. DHSS Hg, Health & Safety Precautions, Technical Guidance Note EH 17, London, HMSO, 1977.
5. Moore, D.J. and A.E. Timbs. *Chemistry in Britain*, 20: 622, 1984.
6. de Mora, S.J. and R.H. Harrison. *Chemistry in Britain*, 1974.
7. Lewis, B.L., P.N. Froelich and M.O. Andreac. *Nature*, 313: 303 and references therein, 1985.
8. Williams, R.J.P. *Proc. Roy. Soc. London.* B213: 361–397, 1981.
9. Williams, R.J.P. *Pure & Appl. Chem.* 55: 1089–1100, 1983.
10. Chem. & Ind. (News), 35, 1985.
11. Roy, P. *Desalination: Water for World Future*, Praeger, 1968.
12. Forman, D. *Chem. & Ind.*, 677, 1983.
13. Nature (News), 313: 620, 1985.
14. Capone, D.G. and M.F. Bautista, *Nature*, 313: 214, 1985.
15. Howells, G.D. and A.S. Kallend. *Chemistry in Britain*, 20: 407, 1984.
16. Paeri, H.W. *Nature*, 313: 747, 1985.
17. Riley, J.P. and R. Chester, Introduction to Marine Chemistry, Academic Press, London, 1971.
18. Chemistry & Industry (News), 3, 1985.
19. Jalees, K. *Chem. & Ind.* 11, 1985.
20. Neftel, A., E. Moor, N. Oeschger and B. Stauffer. *Nature*. 315: 45, 1985.
21. Raynaud, D. and J.M. Barnola, *Nature*, 315: 309, 1985.
22. Wigley, T.M.L. and M.E. Schdesinger, *Nature*, 315: 649, 1985.
23. Folland, C.K., D.E. Parker and F.E. Kates, *Nature*, 310: 670, 1984.
24. Daniels, J.D. *Chem. & Ind.* 126, 1984.
25. Coleman, T. *Chem. & Ind.* 129, 1984.
26. Sharp, B.L. *Chemistry in Britain*, 18: 342, 1982.
27. Jalees, K. *Chem. & Ind.* 142, 1985.
28. Carter, T., J. Butcher and C. Creaser, *Chem. & Ind.* 304, 1985.

IV

BIOLOGICAL SCIENCES

7

Optimizing Soil Environment for Sustained Agricultural Production

N.N. Goswami

Introduction

The word SOIL could be expanded to "Soul of Infinite Life" to signify the importance of soil and its management for sustaining humanity on the Earth's surface (Goswami, 1982). Dr. J.S. Kanwar in his presidential address to the Twelfth International Congress of Soil Science (New Delhi, 1982) observed, "Soil scientists irrespective of their specialization have been concerned with the understanding of processes and the development of techniques for improving soil environments for crop production, . . . they have spent more time on the former than the latter, . . . Rapid increases in demand for irrigation development, fertilizer use and intensive cropping have necessitated critical examination of the concepts and techniques of soil and water management."

At the outset it will be helpful to define the term 'soil environment', though it is difficult to do so precisely. Nevertheless, it can possibly be defined as the interrelationship between the soil, plants and climatic characteristics as reflected on the physical, chemical and biological aspects of soil, such as moisture regime, structure and other physical parameters, nutrient availability and biological activity, erodibility and other forms of degradation, responses of soils to fertilizer, pesticides, water and other inputs. However, since soil itself is a component of the ecosystem comprising soil, plant, animal, human and climate continuum, an impact on any constituent is likely to have some effect on the other parts of the system. The environment of each of these components is intimately linked to one another, so much so that a cleaning up of one environment might adversely affect other constituents. It is similar to throwing 'refuse' into the neighbour's premises to keep one's own environment clean. The question that follows logically then is how could the 'soil environment' be optimized for increasing agricultural production without any impairment to its inherent productivity through processes such as erosion, salinization, waterlogging, nutrient toxicity or deficiency or other forms of land degradation, and at the same time without posing any hazard to the 'environment'.

Modern agriculture relying on extensive use of chemicals, fertilizers and water as inputs with high cropping intensity is exploitative in nature and may often not be compatible with an ideal environment including that of soil's own, unless a sound soil management technology is adopted to optimize the soil environment. To quote Kanwar (1982), "Whether there are disasters like floods or droughts, food or water famines, energy crises or health hazards, poor soil management is the cause."

It is true that in our country use of fertilizer and pesticides have not yet reached the stage as to cause pollution problems arising from them, yet acquiring an understanding of the future risks and problems would help in preventing such hazards. Sandra S. Batie, Prof. of Agricultural Economics at Virginia Polytechnic Institute and State University Blacksburg, USA, recently observed, "there is a need to seek compromise so that public programmes are sensitive to the farmer's unique constraints and the public goal of improved environment. It is time to forge alliances—not conflicts." Prof. Batie referred to some recent events in the U.S.A. relating to pesticide residues in food products, erosion of crop land and a high selenium content in irrigation water, which all reflect public concern with agriculture's impact on environmental quality and moreover they symbolize the changing practices and programmes with respect to environmental considerations.

Therefore, it is now equally important to know not only the soil's ability to produce crops but also to know the impact the agricultural practices would have on the soil and here lies the importance of optimizing soil environment for sustained crop production. The task is at least two-fold (1) to manage 'good soils' without any further degradation through adoption of sound agricultural practices including optimization in the use of water, fertilizer and pesticides, and (2) to improve the so-called 'problem' soil by alleviating soil limitation for crop production through development and adoption of appropriate technology. Optimization of soil environment for crop production would involve (i) root zone oxygen supply, (ii) removal of physical impedence to root development, toxic elements, salinity and alkalinity, (iii) adequate soil water, soil temperature and other physical properties, (iv) adequate nutrient supply in balanced amounts, (v) an optimum soil biological environment.

There are three basic approaches to maintaining an optimum soil environment for crop production—(1) to keep the land fallow for natural rejuvenation, (2) to grow a crop that performs better under the prevailing soil condition (soil-plant adjustment principle), and (3) to match the crop requirements with fertilizers, amendments and other inputs. The first two approaches are of subsistence farming while the latter is based on modern intensive agriculture.

Agricultural Scenario

Out of the 328 million ha of total geographical area in India, the gross cropped area is around 177 million ha and there is not much scope for any further expansion of area under cultivation. Undoubtedly, India has made spectacular advances in improving food grain production, for the total food grain production increased from 51 million tonnes in 1950–51 to estimated 153.6 million tonnes in 1984–85. Yet, Indian agriculture continues to face serious challenges from geometrically multiplying population, fast depleting non-renewable energy sources and continuously degrading soil health. By the end of the present century, we shall have to produce over 225 million tonnes to meet the demands of a projected population of over 935 million. Can these projections possibly be achieved?

It is true that food production has increased remarkably but the analysis of this increase offers some interesting inferences. The magnitude of increase in food production has surpassed the corresponding increase in area under food production, thereby clearly indicating that the average yields of crops have increased. But rates of increases in food production have been much lower than those of fertilizer consumption, expansion of area under irrigation and use of plant protection chemicals etc. Inefficient utilization of available technology, land and other inputs have clearly been responsible for the yield gaps which exist between experimental stations and farmers' fields. For otherwise it should have been possible to double the food production at the present level of input management if the available technology had been applied judiciously. Constraints limiting the crop production might be listed as:

1) Poor soil health and fertility
2) Inefficient utilization of fertilizers including lower levels of application
3) Scarcity and inefficient exploitation of water resources
4) Improper use of plant protection chemicals
5) Lack of awareness about use of farm machinery and implements
6) Socio-economic constraints including poor purchasing capacity of the farmers.

By its very nature, successful agriculture has interfered with the environment. With a view to maximize food production, man has exploited and impoverished the soil fertility, thereby degrading soil health, and developed ways and means (physical, chemical and biological) of eliminating the competing crop species to the benefit of the growth of crop plants, thus disturbing the equilibrium operating in the soil-plant-animal system. In this disturbance, the extensively exploited fields, still open to and part of a larger environment, have potentialities of transmitting their poisonous residues and products to the air, water, animal or plants and eventually these poisons might turn against man. Thus increases in production efficiency are accompanied by greater dangers to our environment. It is true that our national aim and goal is to increase our food production but we have even greater obligations to our future generations to hand over to them the soil in a similar state of health, if not better than which we inherited from our ancestors. Sensing these compulsions, the seventeenth session of the FAO conference held in Rome in 1973 (FAO, 1977) concluded that, "The major environmental problems facing agriculture were not only the avoidance of environmental pollution but also the ensuring, in the development process, of the maintenance of the production capacity of the natural resources for food and agriculture through rational management and conservation measures." Thus the endeavour of soil scientists has to be to develop strategies for maximizing food production without risking soil degradation any further. In essence, soil environment should be optimized. Efficient management practices and strategies have to be developed for optimizing the soil environment of degraded soils which might include all shades of problem soils and harness the potentials of normal soils characterized by poor fertility through various input managements.

Degraded soils include the problem soils which set a limit to crop production due to mineral stress, drought, acidity, sodicity and waterlogging. Eroded soils of the mountainous and sub-mountainous areas are also examples of the degraded soils where top fertile soils have been removed and carried away by flood waters. Principal problem soils in India include saline and sodic, acid, and acid sulphate soils and these constitute nearly 60 million ha of the 142 million ha of net area under cultivation.

Annual loss of arable land through soil erosion is estimated at around 4 to 7 million ha. It would be pertinent to quote from the Frank McDougall Memorial Lecture delivered in 1981 by the late Prime Minister, Indira Gandhi: "The earth has been ravaged desecrated, made sterile perhaps through ignorance in the initial stages but lately driven by greed and arrogance. Today it is not the ignorant but the knowing who pose the main danger to human survival."

Man's greed in our country is exemplified by the large scale deforestation of lands. The results of such deforestation have been alarming and disastrous in the Himalaya as the erosion of fertile top soil from deforested lands has not only silted our reservoirs but also resulted in continuous loss of plant nutrients. According to some estimates, nearly 8.4 million tonnes of plant nutrients are being lost through erosion every year in the country. Considering the magnitude of the problem, immediate conservation measures need to be undertaken for conserving soil through various management practices including afforestation.

Efficient Input Management

In view of the limited scope for bringing more area under plough, increased agricultural production has to come from efficient utilization of fertilizers and plant protection chemicals coupled with selection of proper cropping intensities and crop varieties. This is the key to increasing agricultural production per unit area per unit time. The need for optimization of inputs has been listed as follows:

Water: Soil solution is the aqueous medium that bathes plant roots from which plants obtain their mineral constituents. In addition to acting as a solvent for mineral and organic constituents in the soil system, water is also required for vital physiological processes like photosynthesis and transpiration of crop plants. Thus it will not be an exaggeration to admit that soil management cannot be conceived in isolation from water management.

After independence, a large network of irrigation systems have been developed to meet the water requirements of the crops. In spite of this, the majority of the cultivated area is still under dryland farming. Wherever assured irrigation is available, efforts should be made to increase the efficiency of water use. Research efforts have been made to quantify the role of different inputs such as irrigation on crop growth. The data presented by Pillai et al. (1985) revealed that irrigation was one of the major constraints in crop production. They reported that the wheat yield with optimum irrigation averaged to 31.9 q/ha while without any irrigation it was 19.6 q/ha. The extent of yield reduction in gram, mustard, linseed, black gram and safflower was less than wheat. Optimization of water supply cannot be computed without taking into account the level of fertilization as water and nutrients interact significantly in modifying crop yields. (Goswami and Kamath, 1984). Our studies (Somawanshi and Goswami, 1980) showed that an increase in wheat yield was obtained with increasing levels of *P* at low moisture level or with increasing moisture level at low *P*. Practical implications of these studies indicate that more *P* needs to be added to the crop during periods of low moisture availability than during adequate soil moisture so as to provide optimum *P* nutrition to plants. Prihar et al. (1981) reported that at a given N rate, grain yield increased with an increase in water supply up to a certain level above which it decreased with additional water supply. The threshold water supply and corresponding yield increased with an increase in N rate. It is required that such synergistic interactions whether between water and nutrients or between nutrients themselves, are thoroughly investigated and exploited to the benefit of the farmers as the proper exploitation of these interactions can help in maximizing crop yields without degrading soil environment. It is apt to quote Dr. Swaminathan who, while emphasizing the usefulness of interactions observed, "The success of intensive agriculture may be judged by our ability to harvest the benefits from positive interactions, leaving no nutrient deficiency symptoms uncorrected and by improving the efficiency of applied nutrients.

Whether it is between nutrients or inputs, synergism has to be a useful concept."

While developing irrigation systems and determining the time and amounts of water to be applied, it has to be kept in mind that while under-irrigation does not permit the realization of potential yields, over irrigation and mismanagement of water is likely to cause extensive soil damage through waterlogging and salinization.

It may be mentioned that while the aim under assured irrigation supply is maximization of crop yields, under dryland conditions, these need to be stabilized. The importance of research on optimization of soil environment in dryland area for optimum yields is highlighted by the fact that the government is giving the highest priority to research in dryland agriculture. While addressing the National Development Council on November 8, 1985 our Hon'ble Prime Minister emphasized that the Green Revolution had to be extended to the north-eastern region and dryland areas. The cardinal point in dryland agriculture has been identified as timeliness of operation and best use of the scarce resource water (Randhawa and Sinha, 1985).

Nutrients: Based on calculations by National Commission on Agriculture of India, Kanwar (1982) concluded 130 million tonnes of food grains produced in 1980–81 removed 18 million tonnes of nutrients. The amount of N, P and K added through fertilizer was only 5.5 million tonnes. An additional 5 million tonnes of nutrients could be considered to be replenished through organic resources. This will leave 7.5 million tonnes of nutrients which were drained off from the soil—a heavy drain on the soil reserves indeed. In addition to this, India is annually losing 8.4 million tonnes of N, P and K through erosion. Can the soil bank remain solvent with this type of balance sheet?" This clearly brings out the impact of intensive cropping in depleting the soil of its nutrient reserves. Since the increased agricultural production has to come largely from the existing lands, soil fertility has to be sustained through the continuous application of fertilizers and organics to soil for maximizing crop production. "While it is possible to theoretically calculate the amounts of nutrients which should be applied through organics to completely replenish the lost nutrients, in practice the amount of organics that would be required for this purpose alone would be enormously high. It should also be borne in mind that the demands on organics for several other purposes in our rural context cannot be wished away. Therefore, collection, processing, transport and application of such huge quantities of organics to fully meet the nutrient requirements of the crops will be astounding. In view of these constraints, there is no other alternative but to use fertilizers along with manures." In this context, it is apt to quote Viets (1977) who observed, "I am certain that we cannot solve current and future problems in soil fertility and soil productivity by a nostalgic return to some or all of the practices we used in some former time. We cannot replace much of the commercial fertilizer with organic wastes. We cannot substitute the horse for the tractor. I doubt if we can substitute biotic N_2 fixation for the N fixed industrially. If the field of soil fertility and progress in it goes to sleep, we as scientists will not be meeting our obligations."

Nitrogen: Nitrogen has been universally acclaimed to be a deficient nutrient in the tropical countries of the world and yield responses to applied nitrogen have been almost spectacular. However, at times it has been found that nitrogenous fertilizer responses have not been obtained in the absence of the application of P and K. Data generated from long-term fertilizer experiments have shown that continuous application of N alone to soils have a deleterious effect leading to diminishing yields year after year, particularly in soils where associated nutrients like P and/or K have been deficient and critical for crop growth (Nambiar, 1985). Crop yields with continuous application of N alone to soils during a period of 12 years dropped down to a level that is either equal to or even below the yields recorded where no fertilizer was applied. It shows that the continuous application of nitrogenous fertilizers alone has disturbed the equilibria operating in soil environment and has played a catalytic role in making other elements limit the crop production. This really calls for the balanced fertilization for the maximization of crop yields.

Chemistry of nitrogen availability in the soil-plant system is not fully understood. While nitrogen is the key element in crop production, its behaviour has baffled both soil scientists as well as agronomists. Lower use efficiency of nitrogeneous fertilizers by crops has been a major concern in many investigations and most of the research efforts have been directed at improving the situation. Split application of N within certain limits has been accepted as a universal practice of increasing the use efficiency of nitrogenous fertilizers. Attempts have been made to determine the critical stages of crop growth at which fertilizer use efficiency is maximum and to synchronize the relative rates of the application in such a way that the objective of maximizing the yields with a minimum of fertilizer input is achieved. In the recent past, research efforts have also been made to identify, develop and try slow release nitrogenous materials for the purpose of increasing the utilization of applied N.

While N applications have been useful in increasing the crop yields, these fertilizers (particularly containing N as NO_3^-) have constantly charged the ground water with nitrates and increased the nitrate concentrations in the ground water enormously. Nitrogen has been found to play an important role in the quality of drinking water in connection with the occurrence of nitrite poisoning or methaemoglobinaemia in babies, and cancer in older persons due to the formation of nitrosamine in the digestive tract. Keeping these possible health hazards in view the WHO has recommended the safe level of NO_3—N in drinking water at less than 11.3 mg/l and the unsafe level at more than 22.6 mg/l. Kolenbrander (1982) has calculated the maximum permissible doses of N which could be safely applied to the arable and grasslands of the temperate region having maximum 300 mm drainage per year (Table 1).

TABLE 1

Maximum permissible applications of mineral N kg N ha^{-1} yr^{-1}

Max. leaching loss at 300 mm drainage water, kg N ha^{-1} yr^{-1}	WHO-norm mg NO_3—N 1^{-1} 50 per cent Denitrif		Arable	Land	Grassland	
	—	+	sandy soils	clay soils	Sandy soils	Clay soils
			(kg N ha)			
33	11	+	0	100	320	500
66	22	11	70	360	450	725
132	—	22	260	900	650	1100

Source: Kolenbrander (1982).

Although this situation is not likely to be encountered in India in the near future, one time application of large doses of nitrogenous fertilizers in sandy soils of the Indo-Gangetic plains, needs to be scrupulously avoided as this is likely to lead to putrefaction of water bodies in course of time, besides a valuable natural resource literally going down the drains in the fields. Perhaps realizing this limitation, the Technical Advisory Committee to the Consultative Group on International Agriculture placed maximum emphasis on "improving and maintaining with low inputs the potential of infertile tropical soils" (TAC, 1979). On the other hand, Wild and Cameron (1980) in a very interesting analysis of the data on nitrates in drinking water and N fertilizer application in the U.K. concluded, "Should strict limits be imposed on the use of inorganic fertilizer in an attempt to reduce the amount of pollution, as has often been suggested in the popular press, the resulting decrease in crop production and increase in food prices would pose a far greater problem than the health and environmental threats do at the moment."

Phosphorus: Phosphorus, one of the 'big three' among the essential plant nutrients, because of its key role in the vital energy transformations in living tissues, is rightly called the 'mineral of life.' It is now recognized that P is a major constraint for successful crop production in India, because this nonrenewable finite reserve in soil is being rapidly exhausted leading to its widespread deficiency in areas of high cropping intensity. In India, it is estimated that agricultural crops annually remove about 2.5 million tonnes of P_2O_5 which is almost twice as much as is presumably added through fertilizers. On the other hand, the chemistry of soil indicates that when P is added to a soil in the form of water-soluble chemical fertilizers, approximatety 15 to 20 per cent of P is utilized by the crop to which it is applied, leaving behind the rest to reside in soil in less soluble and more stable forms of decreasing utility to succeeding crops. Keeping these considerations in mind, extensive research efforts have been made, particularly in India, to increase the use efficiency of phosphatic fertilizers.

Of the few techniques developed to enhance efficiency of P utilization in cropping systems, mention may be made of the practice of coating of superphosphate with cow dung slurry and application of superphosphate in conjunction with sodium silicate. For example, in a sandy loam soil of IARI, slurry coating treatment resulted in 19 per cent utilization of fertilizer P as against 14.7 per cent in untreated superphosphate. Similarly in a loamy soil, superphosphate applied in conjuction with sodium silicate at the rate of 150 kg/ha resulted in 20.5 per cent utilization of applied P as against 11.6 per cent from untreated superphosphate (Goswami and Kamath, 1984). In addition to sodium silicate, magnesium chloride farmyard manure and sulphur containing fertilizers have also been found to increase the use efficiency of phosphatic fertilizers.

Investigations have also been made on the efficacy of different methods of P application in increasing its utilization by crops. It has been observed that split application of P at 40 kg P_2O_5 per ha as DAP was superior to basal application in all the four crops (rice, wheat, maize and barley) in increasing P utilization. Dipping of rice seedlings in DAP and coating wheat seeds with DAP have proved efficient in increasing the use efficiency of DAP. Application of Zn and Fe along with NPK also proved useful in increasing the P utilization by maize crop, which shows that the principle of synergy can be employed for the manipulation of a better soil environment.

The basic research on root parameters in relation to P utilization carried out by us at IARI has established the importance of both soil and crop factors as well as soil-plant genotype interactions in improving P utilization by crops. For example, green gram with its relatively lower rate of dry matter production and lower root demand coefficient of P and higher root CEC, showed a higher capacity to extract P from rockphosphate applied to soil while cowpea and soybean registered lower utilization of P from rockphosphates possibly because of their higher dry matter production and capacity to derive P even from a much lower concentration from native soil source.

Since the concentration of P in soil solution is very low, its leaching from agricultural areas and consequent contamination of ground water is virtually negligible. However, erosion of fertile soils is likely to carry with it considerable amount of phosphate which can pollute water bodies.

Rockphosphates and superphosphates also contain appreciable amount of cadmium (Table 2). It is reported that the cadmium in superphosphate is soluble in water and is associated with the phosphate and sulphate contents of the fertilizer. It appears to be as readily available to the plant as the Cd in $CdCl_2$. William and David (1973) reported that the application of superphosphate increased the Cd contents in the tissues of peas, beans, tomato, radish and cabbage. It might be inferred that if the repeated applications of superphosphates were made to the same soil, Cd in the edible portions could have increased to more than 1 ppm, a limit of Cd set to be unsafe in the edible tissues of the food grains (Baker and Chesnin, 1975). It is, therefore, desired that the soils where superphosphates have been regularly applied for a long time, need to be monitored carefully for Cd contents in the soil.

TABLE 2

Total lead and cadmium content of fertilizers (ppm)

	Pb	Cd
CAN	200	6
Urea	4	1
Superphosphate	609	187
Rockphosphate	1135	303
MOP	88	14
DAP	188	109
Suphala	313	89

Source: Singh and Biswas (1982).

Potassium: Next to N and P, K is the element limiting crop production in Indian agriculture, although this view is contested by some who profess that Zn should precede K in importance. However, there is no denying the fact that K is needed for maximizing yields. Research on K has lagged in the past because of the general impression that most Indian soils other than laterites are generally well supplied with this element and that for most crops there is little need for potassic fertilizers (Sekhon and Ghosh 1982). Other factors which have caused K research to progress at a slower pace are the ability of the crops to accumulate K more than their requirement (luxury consumption) and the non-production of potassic fertilizers in the country. The latter view strengthens the belief of planners that if K is not immediately deficient then why exhaust the country's foreign exchange reserves to import K fertilizers. Are these observations correct?

Intensification of agriculture is causing faster depletion of all the nutrients from soils and if the present rate of growth is sustained or accentuated, which is our national necessity, deficiencies of the elements including K would increase progressively. Laterites and lateritic soils are poorest in available K and responses to K in these soils have been spectacular. Even in other soils where intensive agriculture has been practised, responses of varying magnitudes to K applications have started appearing.

In attempts made to study the influence of methods of application on increasing the efficiency of potassic fertilizers, split application has been shown to be a useful proposition in the case of long duration crops, particularly in light textured soils (Srivastava and Hunsigi, 1978).

It is true that a majority of the Indian soils contain adequate amounts of K reserves and are not responding to K fertilizers but these exhaustible reserves are dwindling fast and in course of time are bound to reach a critical stage below which crop growth might not be possible. Chemistry of K in the soil system shows that at such a critical K level supplementation of K is highly unlikely to correct the deficiency because all or a major portion of applied K is liable to be adsorbed and/or fixed by soil thus rendering it unavailable. Hence efficient strategy needs to be worked out to apply K to the soils.

Micronutrients: The adoption of high production technology has caused appreciable reductions in the available micronutrient contents of the soils and therefore micronutrient deficiencies have already started appearing. Prevalence of widespread Zn deficiency in a number of crops growing in different soils of India is now a well recognised fact (Katyal, 1985). Response to applied Zn could be expected in waterlogged soils, alkaline and calcareous coarse textured soils characterized by low organic matter contents. Katyal (1985) reported that in 68 per cent of the experiments conducted on farmers' fields involving rice, yield increase due to Zn was more than 2 q/ha and response to wheat was obtained in 50 per cent experiments. By and large, *kharif* crops like rice, maize and pearl millet were more responsive to zinc. Further, iron, manganese and copper nutritional disorders have also been reported lately.

For sustaining higher crop yields, it is imperative to supplement micronutrients under intensive cropping systems. Corrective measures recommended for alleviating micronutrient deficiencies have been exhaustively reviewed and summarized by Katyal and Randhawa (1983). Both soil and foliar applications have been recommended. As a general rule, soil applications in case of short duration annual crops and foliar sprays in case of perennial horticultural crops have proved beneficial.

Regular applications of Zn even at a dosage of 1 ppm have often resulted in the appreciable build up of zinc in soils. Nambiar and Ghosh (1984) reported that the DTPA extractable Zn in Jabalpur soil increased from 0.7 ppm under NPK treatment to 6.5 ppm in NPK+Zn treatment over a period of 10 years.

It is well known that the ranges between the critical limits of deficiency and toxicity of micronutrients are relatively narrow and if indiscriminate applications of the micronutrients are made, these might build up in the soils to toxic levels. Strategies need to be carefully developed to monitor those fields for available micronutrients where applications of these elements are made. Caution needs to be exercised as the problems due to soil contamination with micronutrients are essentially long-term since the additions are cumulative and may reach the damaging proportions after many years. Once these soils are contaminated, they may remain in that state permanently since the removal of the trace elements either through leaching or by rain water or by removal by other means is an extremely slow process.

In order to minimize the build up of micronutrients, attempts have been made to monitor the residual effects of micronutrients under different cropping sequences. Takkar and Randhawa (1978), from a long-term experiment, reported that the effect of applied Zn (11.2 kg/ha) could not last longer than two crops (one year) in wheat-rice rotation and four to six crops (two to three years) in wheat-maize, wheat-groundnut, potato-*guar* and *reya-mash* rotations. In another study, Takkar et al. (1975) reported that the cumulative effect of 11, 22, 33, 44, and 55 kg/ha of applied Zn was enough for sustaining higher crop production for five, seven, nine, eleven and thirteen crops respectively. These studies are the pointers which call for adjusting the doses of micronutrients as per the requirements of the cropping systems likely to be followed and these should be applied only when needed absolutely as otherwise any indiscriminate application might result in the build up of toxic concentrations in the soil-plant system.

Plant Protection Chemicals

Next to water and fertilizers, plant protection chemicals have become major inputs in intensive agriculture and have considerable influence in modifying soil environment by way of chemical reactions with the soil constituents. With the discovery that the chlorinated hydrocarbons persist for years in soil, all pesticides are now being viewed with suspicion. Some environmentalists hold the view that use of pesticides in agricultural soils should be banned altogether, for the risk involved in such practices is too great to be ignored. On the other hand, agriculturists argue that continued use of pesticides is unavoidable to achieve maximum yields, which is also our national goal. Here again this paradoxical situation needs to be tackled by optimizing the use of chemicals through better understanding of the reaction of pesticides with soil environment.

In India, the use of chemicals has been much lower than in most countries of the world. For example, it is estimated that the average consumption of pesticides is as low as 330 g/ha in India as compared with 1290 g/ha in a developed country like Japan (Sethunathan, 1982). Fortunately, the Indian tropical climate also helps in faster degradation of many chemicals in soils. In spite of that there have been reports that in Delhi, DDT contents of some edible food products have exceded safe limits of consumption, thus posing a greater danger to human beings. Apart from a quest for development and application of safer and easily degradable chemicals, biological control has been tried as an effective remedy. However, the possibilities of an introduced pathogen becoming a pest to some other crop of economic importance or causing infections in animals and man cannot be ruled out and therefore need critical evaluation before adopting these measures on a large scale. Integrated control of diseases and pests, which involves the integration of cultural and ecological control measures with pesticides to obtain the maximum effect with the minimum use of pesticides, is an effective future remedy in reducing the amounts of pesticides being used without decreasing levels of effectiveness or increasing loss (Khan, 1980).

Organic Manures and Amendments

Beneficial effects of organic manures in maintaining higher crop productivity have been known for a long time. Results from long-term fertilizer experiments have shown that on an average, 0.3 to 0.6 tonnes/ha additional foodgrain is possible with the annual application of farmyard manure (FYM) at the rate of 10 to 15 tonnes/ha. In addition to improving the physical conditions, FYM has also been known to act as store-house of nutrients. An application of 5 tonnes/ha can result in the addition of 0.1 kg B, 10 kg Mn, 0.005 kg Co, 0.08 kg Cu, 0.01 kg of Mo (Atkinson, et al. 1954). Though chemical fertilizers are quick in their effect on crops, often resulting in maximum yields, a judicious combination of organic fertilizer has been convincingly shown to help maintain soil environment favourable for efficient crop production in the long run. Partial substitution of fertilizer N up to 50 per cent with organic manure in some crop rotations like rice-wheat, maize-wheat and *jowar*-wheat cropping systems did not cause any reduction in yields and for this reason such practices can go a long way in saving critical inputs like N fertilizer (Pillai et al., 1985).

Use of sewage effluents for irrigation purposes particularly for raising fodder crops is a very old practice in many towns of the country. However, application of sewage sludge to agricultural lands is being viewed with concern by many and it has become a challenge to dispose of it in such a way that is environmentally acceptable, economically feasible and is not hazardous to human health. Just like FYM, sewage sludges have also been helpful in improving the physical soil fertility. For example, at Sabour, the application of dry sludge at the rate of 150 q/ha to supplement 50 per cent nitrogen, 20 per cent P and 30 per cent K decreased the bulk density, increased the infiltration rate, hydraulic conductivity, organic carbon and the aggregates greater than 0.25 mm (Table 3). Additionally sewage is a potential source of plant nutrients as it contains 40 to 60 per cent organic matter, besides considerable amounts of both major (N, P and Ca) and micronutrients (Zn, Cu and Mn etc.). However, their application on agricultural lands is limited by the level of contamination of heavy metals, organic chemical pathogens. Analysing the results of a long-term experiment in the U.K., Brookes and McGrath (1984) reported that amounts of soil microbial biomass were much smaller in soils receiving sewage sludge or sludge containing composts than in soils receiving farmyard manure and the effect was attributed to the toxic metals (Cd, Cu, Cr, Ni, Pb, Zn) present in the sludge.

TABLE 3

Effect of dry sewage sludge on crop growth and soil properties
(Sabour—Sandy Loam)

Treatments	During paddy crop growth		At harvest of wheat crop				Grain yield	
	Organic carbon (%)	Hydraulic conductivity (cm/hr)	Bulk density (g/cm^3)	Organic carbon (%)	Infiltration rate of 60 minutes (cm/hr)	Aggregates 70.25 mm diameter (%)	Paddy (q/ha)	Wheat (q/ha)
T—1	0.540	0.286	1.46	0.33	3.43	50.95	38.8	20.3
T—2	0.583	0.515	1.46	0.38	3.93	55.10	40.9	22.3
T—3	0.783	0.530	1.42	0.44	4.15	68.05	43.6	24.9
T—4	0.736	0.432	1.41	0.47	4.05	69.00	45.8	25.3
T—5	0.747	0.861	1.39	0.46	4.45	65.65	45.9	26.7
T—6	0.836	0.837	1.37	0.54	4.70	71.90	48.5	26.5
T—7	0.703	1.030	1.36	0.51	4.80	72.45	50.6	28.4
C.D. at 5%	0.132	—	N.S.	0.36	—	—	2.8	2.5

T—1: Control (No Sewage Sludge) + 100 kg N + 60.00 kg P_2O_5 + 40.00 kg K_2O/ha
T—2: Sewage Sludge @ 50 q/ha + 83.33 kg N + 55.83 kg P_2O_5 + 35.83 kg K_2O/ha
T—3: Sewage Sludge @ 100 q/ha + 66.66 kg N + 51.66 kg P_2O_5 + 31.66 kg K_2O/ha
T—4: Sewage Sludge @ 150 q/ha + 50.00 kg N + 47.50 kg P_2O_5 + 27.50 kg K_2O/ha
T—5: Sewage Sludge @ 200 q/ha + 32.33 kg N + 43.33 kg P_2O_5 + 18.17 kg K_2O/ha
T—6: Sewage Sludge @ 250 q/ha + 16.66 kg N + 39.17 kg P_2O_5 + 9.17 kg K_2O/ha
T—7: Sewage Sludge @ 300 q/ha + 0.00 kg N + 35.04 kg P_2O_5 + 15.00 kg K_2O/ha
N.S. : Not significant
Source: Gupta (1983).

With a view to minimize the heavy metal build up due to repeated applications of sludges, certain guidelines have been set on the maximum amounts and rates of sludge which could be applied without any fear of heavy metals toxicity. Assuming that the toxic effects of heavy metal were additive, Chumbley (1971) introduced the concept of zinc equivalent which was defined as Zn+2 Cu+8 Ni. It was suggested that 560 kg/ha of zinc equivalent to the sewage sludge could be safely applied over a long period, say 30 years, provided the pH did not drop below 6.5. Using sugarbeet, celery and lettuce as test crops, Marks et al., (1980) reported from a field study that the relative toxicities of Zn/Cu/Ni were 1/0.8–1.3/1.8–4.9, with celery being insensitive to copper. Mitchell et al., (1978) found these elements to be equally toxic to wheat in soil of pH 7.5 but the ratio of Zn/Cu/Ni was 1 : 4 : 6 in soil of pH 5.7. It is clear that the relative toxicities of elements are likely to vary with the choice of crops and soil conditions. But still the concept of zinc equivalent has been retained in the latest British guidelines because of its simplicity.

A glaring omission in the 'zinc equivalent' concept is that of Cd toxicity. Sewage sludges from many municipalities have been reported to be rich in Cd content and Cd has the potential of getting easily absorbed by the crop plants. Its inclusion in the guideline is needed urgently because whereas Zn, Cu and Ni toxicities effects are largely confined to depressed growth and yields of crops, Cd has been found to cause a large number of disorders in animal and human systems in addition to creating the phytotoxicities. Cadmium management gets further complicated by the fact that the Cd levels in the food grains at which these become toxic to animals are much lower than those at which yield decreases are manifested. Guidelines for sewage sludges application have been summarized by Webber (1981).

Recognizing the potentialities of Cd as a pollutant it has been suggested that the sewage sludges containing high Cd levels should be pretreated with Zn to yield a Cd : Zn ratio of 0.01. Beneficial effects of such a treatment are due to the fact that (a) Zn accumulates to phytotoxic levels much before sufficient Cd can be absorbed to endanger the chain, (b) Zn inhibits Cd uptake by dicotyledonous plants at low Cd/Zn ratios, and (c) Zn alleviates injuries from excessive levels of Cd in animals.

Biofertilizers

In the pursuit of exploiting natural resources for maximizing crop production, the use of natural biological agents as catalysts in enhancing production efficiency has been steadily gaining popularity. Materials like *Azolla*, *Rhizobium*, *Azotobacter* and *Biejerinckia* as inoculants have been tried in both green houses and on field scales, the details of which can be obtained in an interesting article by Gaur (1982). Use of these materials in increasing the production of pulses and rice has assumed importance. Pillai et al., (1985) reported that the inoculation of *Rhizobium* had a positive influence on increasing the grain yield of green gram and cowpea at Bichpuri, green gram and black gram at Hissar and groundnut at Akola. Kundu and Gaur (1980) reported that grain yield and uptake of N and P by wheat were increased due to *Azotobacter* inoculation alone and also due to combined inoculation of Azotobacter with phosphobacteria like, *Pseudomonas striata* and *Bacillus polymyxa* in both sterilized and non-sterilized alluvial soils in Delhi. The combined inoculation gave maximum response, thus showing useful synergistic effects.

In recent years, mycorrhizal association with the root system of crop plants has assumed importance in mineral nutrition of plants, particularly with respect to P and micronutrients like Zn, etc. Inoculation with vesicular arbuscular mycorrhiza has been useful in increasing the use efficiency of P fertilizer (Table 4). Hence the realization that biologically fixed released nutrients can also supplement and substitute partially the industrially fixed ones has led to the scientific investigations in this direction and the above results indicate the possibility of increasing the utilization of added fertilizers by biological agents and of fixing the atmospheric N in the soil.

TABLE 4

Per cent P utilization by wheat-cowpea-rice cropping system as affected by mycorrhizal inoculation

Treatment	Soil		
	Alluvial	Black	Red
Superphosphate	20–28	40–44	30–32
Superphosphate + Inoculation	30-32	50–53	32–38
Dicalcium phosphate (DCP)/ Rockphosphate (R.P.)	11-19	11-31	3–19
DCP/R.P. + Inoculation	19–29	20–48	25–34

Source: Goswami and Kamath (1984).

Agro-techniques

CROPPING SYSTEM

Adoption of high production technology is likely to cause depletion of nutrients from soil and deteriorate soil health. On the other hand, maximizing crop yields without degradation in soil health is what is desired. Attempts should therefore be made to select cropping systems which give higher yields without placing much stress on soil fertility. Sadanandan and Mahapatra (1973) showed that rice-rice and rice-jute-rice cropping systems were very intensive in causing decrease in total N content whereas potato-rice-rice, maize-rice-rice and groundnut-jute-rice placed only moderate stress. Intensive cropping (taking crop continuously for six years) experiments, under standard recommendations of fertilizer doses, conducted by Sharma et al., (1980) revealed that the highest and lowest available N, P, K contents were recorded in samples from maize-potato-potato-*moong* and groundnut-wheat-fallow crop rotations. Of course, the build up was in direct proportion to quantities of fertilizers added. It can be inferred that depending upon the input resources available with farmers, the rotations helpful in sustaining soil productivity should be selected. For a long time, a necessity has been felt for making studies which might be useful in determining the crops in rotation from the fertility investigations point of view. Our own studies at IARI (Gajbhiye and Goswami, 1980) have shown that cropping with wheat was helpful to *bajra* for the Ca requirement of the latter while *bajra* cultivation helped towards the Mg, Fe, Mn and Zn requirement of the former, thus making wheat-*bajra* cultivation a most compatible one from the point of view of secondary and micronutrient management. This approach offers a basis for determining the crops to be included in cropping systems for efficient utilization of nutrients by way of exploiting principles of complimentality.

Some crop rotations mine nutrients at faster rates than others without producing additional economic yields. Since one of our national objectives is to maximize crop yields per unit area per unit time with the minimum degradation of soil environment, long-term measures have to be undertaken in selecting cropping patterns in such a way that these exploit residual fertility more efficiently. Randhawa and Sinha (1985) have listed prominent stable crop rotations suitable for different agroclimatic regions.

Intercropping is another useful practice in managing crop strategies. Proper selection of crops as intercrops and standardization of cultural practices might go a long way in sustaining crop production with minimum stress on soil environment. Growing crops of dissimilar growth patterns, such that the periods of growth do not coincide, would ensure optimum productivity of two crops growing in association (De, 1979). Inclusion of legumes as an intercrop has often benefited the non-legume component (Table 5). The additional

TABLE 5

Nitrogen yield (kg N/ha) in maize and sorghum grown in intercropping systems with different grain legumes

Intercropping systems	Nitrogen yield (kg N/ha)	
	Maize	Sorghum
Cereal alone	90.2	123
Cereal + groundnut	94.9	131
Cereal + moong	99.1	126
Cereal + cowpea	98.3	143
Cereal + black gram	100.7	142

Source: De (1979).

nitrogen harvested in maize ranged between 4.7 and 10.5 kg N/ha, the highest amount having been derived from black gram association. A maximum 20 kg/ha increase was obtained in sorghum grown in cowpea association. Similarly, growing of legumes as an intercrop might also prove beneficial in increasing water use efficiency.

Soil-plant Adjustments

In recent years, soil chemists have turned towards a more economical solution to the soil toxicities and deficiencies using the principle of varietal tolerances. Varietal tolerance to toxicities of Al may be comparable to salt tolerance but the varietal tolerance for P deficiency may be related to more efficient utilization of soil P (Koyama et al., 1973; Gines et al., 1977). The varieties may also have the preferential ability to take up different types of phosphate. For example, rice var. H-4, noted for its tolerance to P deficiency on acidic soil, was the most susceptible one on an alkaline soil (Katyal et al., 1975).

Brar et al. (1974) observed differential responses of maize cultivars to Zn. The less responsive local variety absorbed more Zn from the deficient soil and had narrow P/Zn, Fe/Zn and Mn/Zn ratios in plant issue than the more responsive hybrid Ganga-5.

Iron deficiency and Mn and Al toxicities on acid soils are mineral-induced plant stresses that limit the yield on dry land. Howeler and Cadavid (1976) reported that Al tolerant cultivars had higher levels of P and Ca and lower levels of Al in their shoots than Al susceptible ones.

Conclusions

Soil is the essence of life. It is an axiom that "the wealth of a country lies in her soil and her prosperity in its intelligent management." In order to maximize production and to sustain soil productivity, it is imperative that every ha of land be used according to its capability and that the soil environment is optimized. The soil environment is not the few top cm of soil but it encompasses the soil layers below it (the subsoil) down to the ground water table, the topography, vegetation and the climate within and above it; and an optimum soil environment does not mean only maintaining the environment or health of the soil for crop production. It must take into account the effect of all practices, cultural, mechanical, chemical, and all inputs such as fertilizer, water and chemicals on the soil-plant-animal-human-climate as a whole.

There is no alternative to the increased use of water, fertilizers and plant protection chemicals, for the present. However, their use should be moderated by way of increasing their use efficiencies with cultural manipulations, continuous use of organic sources and manures in cropping systems, exploiting the benefits of soil-plant adjustments and selection of proper cropping patterns. Such practices will go a long way in sustaining crop production without much threat of degradation of soil environment.

In this context, it might be pertinent to quote Pal (1982), an eminent agricultural scientist and former chairman, National Committee on Environmental Planning and Coordination who observed, "while there can be no two opinions about the value of judicious use of fertilizers to enhance food production, steps must be taken to avoid excessive and imbalanced use, which in the long run may damage the soil and also create environmental problems. Even the relatively small use of pesticides in India has not prevented the appearance of residues in a variety of marketed food and food material. Other ecological damage (to beneficial organisms, soil quality, etc.) has yet to be properly documented.

The increase in food production in the future has to be achieved to a great extent through vertical expansion (including increased cropping intensity) and much less through horizontal expansion. Increase in yield on the same piece of land will involve greater use of fertilizers, water, chemicals and involve tremendous amounts of an intensive form of operation and capital investment with the attendant problems. Obviously, more and more newer problems which were hitherto unknown would appear on the surface with the increase in intensity of cropping and higher agricultural production. This would involve a great deal of exploitative agriculture, and unless the anticipated problems can be foreseen and suitable remedies adopted in advance the soil will be impoverished, depleted or even degraded. Thus, if the beginning of the Green Revolution was set forth by the 'miracle' varieties of the plant scientists, the permanency of it for a sustained production, that is, maintenance of the new yield 'plateau', would be the responsibility of the soil scientists. The soil scientists must think of both preventive and curative measures of the problems of soil degradation, and contamination for maintaining the soil health. The problems associated with deficiencies of secondary nutrients and micronutrients, nutrient interactions, and pesticide residues have to be tackled; and production has to be stepped up manifold from the same area without any detriment to the environment and ecological balance.

For optimizing the soil environment it may be worthwhile to follow the following guidelines:

1) To use the soil according to its capability; over exploitation should be avoided.

2) To adopt the most appropriate cropping sequence based on complementality, soil exhausting and soil restoring crops both be grown in the sequence. Inclusion of legumes in the cropping sequence should be a good practice.

3) To increase the efficiency of the production inputs—fertilizer and water. This will by itself lessen the chance of environmental pollution and soil degradation.

4) To increase the productive capacity of the soil through use of organic manures, green manures, etc. This will improve the soil physical condition

and increase the soil biomass and microbiological activity and also prevent deficiencies of some of the secondary and micronutrients.

5) To use fertilizer based on appropriate soil tests.

6) To use biofertilizers.

7) To intensify organic recycling.

The main aim of optimizing soil environment should be to improve the productivity of the land already under the plough and to prevent soil degradation, and to restore the degraded land back to normal production.

The soil (land) has been called as the 'mother' in the Vedas and I am the son of this expansive earth [माता भुमिः पुत्रो अहं पृथिव्याः (अथ० 12.1.12)]; it is the soil which is the source of all well being. I would like to conclude with the prayer

यस्यां समुद्र उत सिन्धुरापो यस्यामन्नं क्रृष्टयः संबमूवुः ।
यस्यामिदं जिन्वति प्राणदेजत् सा नो भूमि पूवपेये दधातु ॥

(AV.12.1.3)

"Let that earth (the soil) put us into the same rich fortunes, which were enjoyed by our predecessors. Upon which flourish the oceans, great rivers and other types of waters, which causes and produces different kinds of grains and other vegetations, and which nourishes all the breathing and moving animates." (Varma and Goswami, 1982).

REFERENCES

Atkinson, H.J., G.R. Giles and J.G. Desjardins. *Can J. Agric. Sci.* 34: 76–80, 1954.

Baker, D.E. and L. Chesnin. *Adv. Agron.* 27: 305–376, 1975.

Brar, S.P.S., N.S. Randhawa and R. Dwivedi. Plant Analysis and Fertilizer Problems. In: J. Wehrmann (Ed.), *German Society of Plant Nutrition.* pp. 55–67, 1974.

Brookes, P.C. and S.P. McGrath. *J. Soil Sci.* 35: 341–346, 1984.

Chumbley, C.G. *ADAS Adv. Paper* No. 10, MAFF, London, 1971.

De, R. In: IAEA-TECDOC-235, Technical Document Issued by International Atomic Energy, Agency, Vienna (1980), pp. 73–84, 1979.

FAO. The State of Food and Agriculture, Rome, p. 32, 1977.

Gajbhiye, K.S. and N.N. Goswami. *J. Indian Soc. Soil Sci.* 28: 501–506, 1980.

Gaur, A.C. In: Review of Soil Research in India, Pt 1, *Indian Soc. Soil Sci.* pp. 278–305, 1982.

Gines, H. *et al.* Quoted by Ikehasi, H. and Ponnamperuma, F.N., *Soils and Rice*, IRRI, Manila, Philippines, p. 818, 1978.

Goswami, N.N. Whither Soil Research, *Trans. 12th Int. Congr. Soil Sci.* 5: 103–120, 1982.

Goswami, N.N. and M.B. Kamath. *Fertil. News* 29 (2): 22–26, 1984.

Gupta, R.P. *SPC Bull.* No. 2, IARI, New Delhi, 1983.

Howeler, R.H. and L.F. Cadavid. *Agron. J.* 68: 551, 1976.

Kanwar, J.S. *Indian Fmg.* 18 (10): 5–8, 1979.

Kanwar, J.S. Managing Soil Resources to Meet the Challenges to Mankind, Presidential Address, *Trans. 12th Int. Congr. Soil Sci.* 1: 1–32, 1982.

Katyal, J.C. *Fertil. News* 30 (4): 67–80, 1985.

Katyal, J.C. and N.S. Randhawa. Micronutrients, FAO Fertilizer and Plant Nutrition Bulletin No. 7, 1983.

Katyal, J.C., D.V., Seshu, S.V.S. Sastry and W.H. Freeman. *Curr. Sci.* 44: 238–240, 1975.

Khan, S.U. *Pesticides in the Soil Environment*, Elsevier Scientific Publishing Company, Amsterdam-Oxford-New York, 1980.

Kolenbrander, G.J. Whither Soil Research, *Trans. 12th Int. Congr. Soil Sci.* 5: 248–266, 1982.

Koyama, T., C. Chammek and P. Switwonge. *Trop. Agric. Res. Cent. Jpn. Tech. Bull.* 4: 32, 1973.

Kundu, B.S. and A.C. Gaur. *Pl. Soil* 57: 223–230, 1980.

Marks, M.J., J.H. Williams, L.V. Vaidyanathan and C.G. Chumbley. MAFF Reference Book 326, London, HMSO, 1980.

Mitchell, G.A., F.T. Bingham and A.L. Page. *J. Environ. Qual.* 7: 165–170, 1978.

Nambiar, K.K.M. *Fertil. News* 30 (4): 56–66, 1985.

Nambiar, K.K.M. and A.B. Ghosh. LTFE Res. Bull. No. 1, IARI, New Delhi, 1984.

Pal, B.P. Souvenir, *12th Int. Congr. Soil Sci.* 124–127, 1982.

Pillai, K.G., L. Suseela Devi and K.T.P. Setty. *Fertil. News.* 30 (4): 26–34, 1985.

Prihar, S.S., K.S. Sandhu, Y. Singh and R. Singh. *Fertil. Res.* 2: 211–219, 1981.

Randhawa, N.S. and A.K. Sinha. *Fertil. News.* 30 (4): 19–25, 1985.

Sadanandan, N. and I.C. Mahapatra. *J. Indian Soc. Soil Sci.* 21: 173–175, 1973.

Sekhon, G.S. and A.B. Ghosh. Review of Soil Research in India Pt 1, *Indian Soc.* pp. 331–341, 1982.

Sethunathan, N. Review of Soil Research in India Pt 1, *Indian Soc. Soil Sci.* pp. 269–277, 1982.

Sharma, K.N., B. Singh and D.S. Rana. *J. Indian Soc. Soil Sci.* 28, 173–177, 1982.

Singh, R. and B.C. Biswas. Whither Soil Research. *Trans. 12th Int. Congr. Soil Sci.* 5: 227–247, 1982.

Somawanshi, R.B. and N.N. Goswami. *J. Indian Soc. Soil Sci.* 28: 131–133, 1980.

Srivastava, S.C. and G. Hunsigi. Proc. Int. Potassium Symp. Potash Res. Inst. India, New Delhi, p. 261, 1978.

TAC (Technical Advisory Committee to the Consultative Group on International Agricultural Research). TAC review of priorities for international support to agricultural research, TAC Document No. AGD/TAC: IAR/79/1, 1979.

Takkar, P.N., M.S. Mann and N.S. Randhawa. *J. Indian Soc. Soil Sci.* 23: 91–95, 1975.

Takkar, P.N. and N.S. Randhawa. *Fertil. News.* 23 (8): 3–26, 1978.

Varma, S.K. and N.N. Goswami. Souvenir, *12th Int. Congr. Soil Sci.* pp. 11–13, 1982.

Viets, F.G. (Jr.), *Soil. Sci. Soc. Am. J.* 41: 242–249, 1977.

Webber, J. In: Lepp, N.W. (ed.) *Effect of Heavy Metal Pollution on Plants*, Vol. 2, Applied Science Publishers, London and New Jersey, pp. 159–184, 1981.

Wild, A. and K.C. Camerona. Soil Nitrogen as Fertilizer or Pollutant, IAEA, Vienna, pp. 289–306, 1980.

William, C.H. and D.J. David. *Australian J. Soil Res.* 11: 43–56, 1973.

8

Some Stressed Habitats, Functioning of Their Communities and Proper Management

L.P. Mall

Introduction

I wish to highlight some stressed habitats. In recent years biologists have adopted the term "stress" for any environmental factor potentially unfavourable and capable of inducing a potentially injurious strain to living organisms. The main environmental stresses can be categorised as indicated in Chart 1 (modified from Levitt, 1980). These stresses can be natural or man-made, directly or indirectly.

Some Natural Stressed Habitats

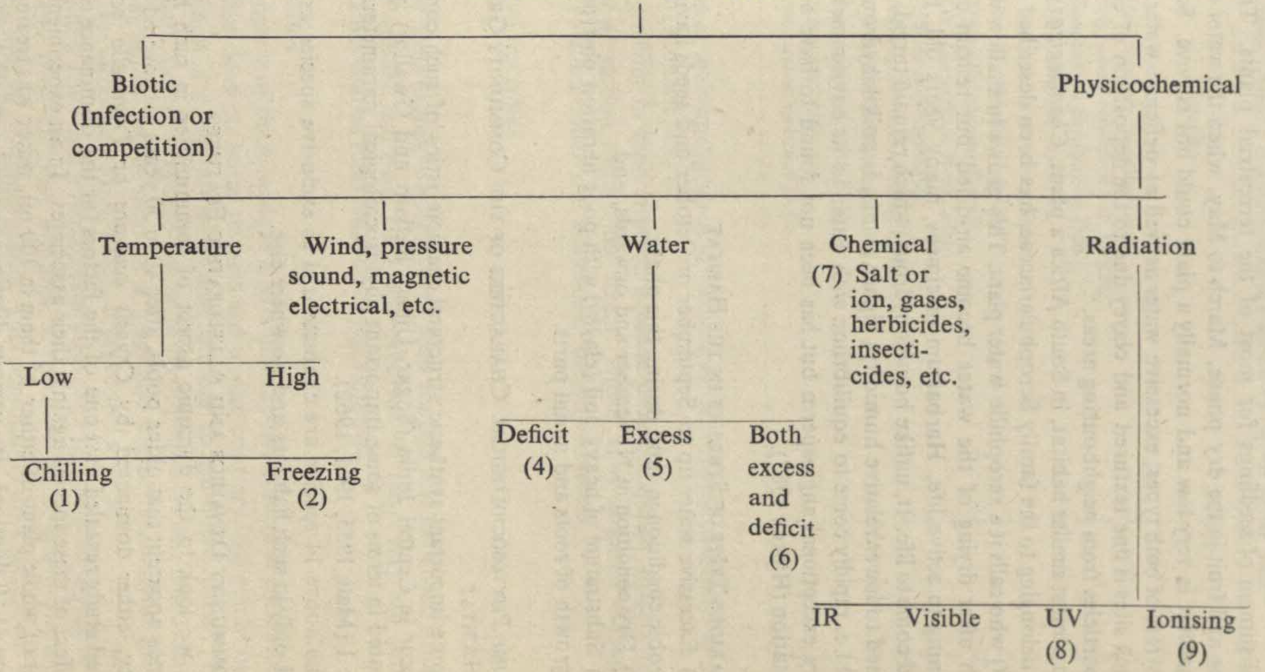
Habitats with excessive as well as deficient water:

1) GENERAL FEATURES

There are several excavated grounds changed into small pools, depressions, shallow pans, along railway tracks, road sides, and the like due to the removal of ground material. These depressions, ranging normally in depth from 0.5 metre to more than 1.5 metres, get filled with water during the rains (July-August) and remain covered with water till September-November, depending upon their depth. After drying of the surface water some very special types of plants, forming a special community, appear although seeds of many other species of plants come in the depression. These seeds remain in the mud, covered with water almost in an anaerobic condition, a condition unfavourable to seeds of most terrestrial plants. Such plants, thus pass some of their

CHART 1

ENVIRONMENTAL STRESS


Biotic
(Infection or competition)
Physicochemical
Temperature
Wind, pressure sound, magnetic electrical, etc.
Water
Chemical
(7) Salt or ion, gases, herbicides, insecticides, etc.
Radiation
Low
High
Chilling (1)
Freezing (2)
Deficit (4)
Excess (5)
Both excess and deficit (6)
IR
Visible
UV (8)
Ionising (9)

life (seed condition) in excessive water and many of them are capable of germinating in waterlogged soils, normally unsuited for germination, and establishment of seedlings for most of the terrestrial plants. They grow, flower and fruit in the dry phase, March to May, when the water content of the habitat is very low and normally a plant could not survive. Such plants face stress of both types, excessive water as well as deficient water. The soil of such sites is fine textured and clayey due to the deposition of eroded fine soil particles from neighbouring areas.

In almost similar habitat, in South Africa a plant, *Chamaegigas intrepedus* Dtr. belonging to the family Scrophulariaceae, has been described by Hickel (1967) who calls it a xerophilic water plant. This grows in shallow water pans which after drying of the water become air-dried but remain capable of returning to active life. Harbarium specimens, many years old, have been found come to life. It, unlike homoiohydrous (which remain turgid, although, exposed to lower relative humidity) higher plants, is poikilohydrous (Walter, 1955) i.e. rapidly come to equilibrium with water in its environment. This is a very exceptional angiosperm but has been not found to have any special adaptation (Hickel, 1967).

2) VARIOUS TYPES OF STRESSES IN THE HABITAT

a) Excessive water up to September or October and seeds having to face anaerobic condition in mud during this phase,

b) Dry condition in November and onwards, and

c) Substratum of heavy soil (clayey) with poor aeration obstructing normal growth of roots and aerial parts.

3) SOME PHYTOSOCIOLOGICAL CHARACTERS OF THE COMMUNITY GROWING IN THE HABITAT

Some important synthetic structural characteristics of such communities as occur in Central India (Sagar, Ujjain, Ratlam and Gwalior) have been evaluated in terms of some important phytosociological parameters, given in Table 1 (Mall, 1955, 1961, 1962).

The above 14 species are characterized as exclusive species as they are found only in such habitats and no where else.

4) COMMUNITY DYNAMICS AND ALLELOPATHIC FEATURES

If we look to the dynamic aspect of communities in such habitats it becomes apparent that older pools, after 40 to 50 years get covered by a community, either dominated by *Crypsis aculeata* or *Trigonella occulta*. A detailed study revealed that one of the factors for the dominance is allelopathic effect of these species against their associates. In an experiment 5 kg dry weight of whole plant of either of them in 100 ml, water was treated as stock solution (1 : 0 dilution). Its various dilutions showed a marked effect on the

TABLE 1

Some synthetic characteristics of common species of drying pools

S. No.	Species	Fidelity class	Presence class
1	*Heliotropium supinum* Linn.	5	5
2.	*Polygonum plebejum* var. Griffith	5	5
3.	*Gnaphalium pulvinatum* Debile	5	3
4.	*Glinus lotoides* D. Kze.	5	2
5.	*Chrozophora prostrata* Daiz.	5	2
6.	*Crypsis aculeata* (L.) Cut.	5	2
7.	*Trigonella occulta* Debile	5	2
8.	*Cochlearia flava* Bvch. Ham	5	1
9.	*Althaea ludwidgi* Linn.	5	1
10.	*Polypogon monospeliensis* Darf.	5	1
11.	*Sphaeranthus indicus* L.	5 less than	1
12.	*Polanisia chelidonii* D.C.	5	1
13.	*Scirpus michelianus*	5	1
14.	*Nastartium indicum* D.C.	5	1

germination of the wheat grain and seeds of some common associates as given in (Table 2) (Moharir, 1979).

Plants growing in such stressed habitats develop special characteristics which offer protection against the strain. These, they acquired during the course of evolution under the influence of the environment.

5) ADAPTIVE FEATURES

a) Seeds

Seeds of some exclusive species have been studied and have been found to have some special features. They can be dried to have very low level of moisture (2 per cent or less) without losing viability.

b) Germination

Submergence of these seeds in mud under almost anaerobic condition for a few months does no harm to them and on the contrary, the condition has become almost a prerequisite to enable them to germinate (Mall, 1954). Such an adaptation is very rare among seeds of plants. It was noted that due to remaining embedded in mud for a long time the permeability of the seed coats to water increases (Mall, 1955), as given in Table 3.

The shallow pans or depressions start developing, just after drying of their surface water from October onwards, a special type of plant community, mostly consisting of prostrate plants. This community does not appear in the warm months of August or September, even after the pools get dried up

TABLE 2

Effect of plant extracts of *Crypsis aculeata* and *T. occulta* on germination of seeds of wheat, *P. plebejum*, *G. indicum*, *G. lotoides* and *H. supinum*

	Dilution	pH	Germination % of						
			T. vulgare	*P. plebejum*	*G. indicum*	*G. lotoides*	*H. supinum*	*T. occulta*	*C. aculeata*
Crypsis aculeata	1 : 0	5.5	0	4±1.2	5±1.4	2±1.7	4±1.3	85±2.8	
	1 : 10	6.3	39±2.6	22±3.0	23±1.4	48±1.6	25±2.6	90±3.5	
	1 : 250	6.8	95±3.6	75±2.8	85±2.6	80±3.4	78±2.8	96±2.0	
	Control	7.0	97±3.0	76±3.4	90±3.5	83±2.8	82±3.5	97±2.1	
Trigonella occulta	1 : 0	5.2	0	5±1.4	3±1.2	7±1.3	5±1.5		80±2.8
	1 : 10	6.2	42±2.0	27±3.7	36±2.6	31±2.6	31±2.6		85±3.4
	1 : 250	7.0	96±2.8	73±3.0	89±3.1	80±2.6	76±3.0		95±2.0
	Control	7.0	97±3.0	76±3.4	90±3.5	83±2.8	82±3.4		96±2.1

TABLE 3

Permeability of seed coat with and without mud treatment

Spec.	Treatment	Water absorbed (%)				
		1/2 hr.	3 hrs.	19 hrs.	4 days	7 days
H. supinum	Without mud treatment	5.6	5.6	11.2	11.4	10.2
	With mud treatment	4.6	14.6	15.4	15.8	24.2
P. plebejum	Without mud treatment	1.9	5.8	12.1	12.2	16.4
	With mud treatment	3.6	16.3	19.2	23.8	28.5

because during that period the minimum temperature does not fall to 9 to 14°C in the fields. The seeds have be now acquired a requirement of low temperature for at least two hours daily but the maximum germination occurs when low temperature is there for 12 hours daily. If the minimum of two hours of low temperature is given on alternate days only, some of exclusive species, such *H. supinum* and *C. oculea* fail to germinate as is given in Table 4.

TABLE 4

Effect of low temperatures period on germination of seeds of some species

	Per cent germination when exposed							9°C for 2 hrs. on alternate days
	Only 1 day for			daily to 9°C for				
	4	8	Hrs.12	30	0	Hrs.2	30	
H. supinum	0	0	0	52	0	5	5	0
P. plebejum	24	24	72	30	54		86	30
G. lotoides	0	0	16	32	40	98	96	40
T. occulta	0	0	25	32	0	24	30	20
C. oculea	0	0	0	16	0	5	15	0

Thus the appearance of this plant community depends on the seeds being embedded in mud and having low temperatures during drying of surface water. Many of them are capable of germinating even when the soil is waterlogged and there is some trace of surface water.

There is some characteristic change in nucleic acids from maturity to various later stages, up to germination.

c) Root system

Roots of many of the species are characterized by a wavy appearance instead of being straight presumably due to soil being heavy as it is mostly clayey and thus offers resistance to the penetration of the roots.

d) Allelopathic effect

As pointed out earlier some sites which are old show dominance of either *Crypsis aculeata* or *Trigonella occulta*. They gain dominance perhaps due to early germination of their seeds during drying, their alellopathic effects on associates, and better developed root system as they show higher root: shoot ratio (1 or more) as compared to many others (about 0.1).

The community is by no way important for dry matter production which is 3.0 g m^2/day (Moharir, 1979). The climax species, *C. aculeata* and *T. occulta* are prostrate and create difficulty in grazing by cattle.

Due to modern science and technology, however, some of these habitats are being used to grow crop plants, especially with late varieties of wheat, gram and lens.

Mangrove Habitats

On upper intertidal zones of sheltered coastlines, estuaries, lagoons, and the like, mangrove forests normally develop and are named mangrove habitats.

1) General features of mangroves

Mangroves are characteristic littoral plant formations of tropical and subtropical sheltered coastlines. They have special characteristics due to their physiognomy, i.e. low (up to 10 m high) and high (20 m or more in height) types of forest (West, 1956), mostly light green in colour with various types of aerial roots—prop, stilt, knee-like, finger-like vertical, conical, vertical or blade like. They have very extensive terrestrial roots mostly horizontally extended and at places exposed due to soil erosion. Most of the mangrove plants, about 50 per cent based on density, produce viviparous seedlings hanging from fruits on trees.

Mangroves, generally, occur on zones between the high water levels of neap and spring tides. According to Scientific Committee on Oceaning Research (SCOR) or the Commission on Ecology working groups (COE) (1983), the total area of mangrove in the world is 1,61,937 sq km in altogether 64 countries. The total number of exclusive tree and shrub species is 60 and non-exclusive ones total 23.

2) Different types of stresses in mangrove habitats

Various stresses operating in mangrove habitats are as follows:

a) High degree of salinity in substratum and surface water ranging from

1.2 to 4.0 per cent or more and seasonal fluctuations due to the incoming of freshwater from high lands.

b) High ratio between two chemically similar elements, sodium and potassium, amounting to 40 : 1 in molar strength creating difficulty in absorption of K^+ ion which is an important essential element.

c) Periodic inundation of the substratum and lower portions of tree branches with water and subsequent exposure causing difficulty in important physiological functions.

d) Deficiency of nutrients, particularly fixed nitrogen, in substratum and surface water, accentuated by export of particulate matter.

e) Anaerobic or near anaerobic condition in the substratum, making normal functioning of roots very difficult.

3) Adaptive features to cope with the stresses

a) High degree of salinity—The salinity, in exceptional cases, may go up to 9 per cent and *Avicennia marina* has been found growing in such situations and the species is said to be a very great salinity tolerant, growing in almost fresh water to very high salt concentration (9.8 per cent). Due to salinity the DPD of the substratum remains high creating difficulty in water absorption. Also excessive sodium ions in plant tissues prove toxic and cause injury. At the same time it also inhibits ATPase activity on membranes disturbing the cation pumping system due to which the potassium ion is kept out of tissue instead of sodium ion. Mangroves resist high salinity in the following ways:

Ultrafiltration mechanism: Scholander et al. in 1962 showed that the xylem sap in many mangroves did not have very high salt contents but 10–50 times only of normal plants. In salt secreting types it was 10 times. Through a simple experiment (Scholander et al., 1965) with *Rhizophora* pressurized root system it was demonstrated that the mangrove separates fresh water from sea water by a simple non-metabolic ultrafiltration process, which is unaffected by chilling and poisoning with dinitrophenol (DNP) or carbon monoxide at 20 atm. All the mangroves investigated (Scholander, 1968) had a negative xylem pressure of about 30–60 atm., serving as a driving force for salt filtration.

Secretion of salts through glands: Aegialitis spp. *Aegiceras* spp. *Avicennia* spp. and *Acanthus* spp. secrete salts through glands on the leaf surface. These glands in *Avicennia* and *Acanthus* have an indefinite number of cells (usually between 5 and 9). They are supposed to transport ions against a concentration gradient. Various inhibitors (pot, cyanide, sodium azide, sodium fluoride, arsenate and carbonyl cyanide 3-chlorophenyl-hydrazone) at a concentration of usually more than 5×10^{-3} M inhibit markedly the process of secretion. Usually the ions secreted are in the same proportion as in sea water and light has been found to influence secretion, which is more in day time than during night, the highest being during noon (Scholander et al., 1962).

Anaerobic condition checks secretion of salts. The secreting types show a smaller content of cation in leaves than non-secreting type (*Rhizophora*, *Bruguiera*, etc.) as given in Table 5.

TABLE 5

Ion content of leaves of *Rhizophora mucronata* and *Aegialitis annulata* (in parentheses)
(After Atkinson et al., 1967)

S. No.	*Age of leaves	1	2	3	4	5
1.	Dry wt. (g/leaf)	0.16 (0.316)	0.50 (0.456)	0.50 (0.445)	0.60 (0.500)	0.63 (0.400)
2.	Water (%) (f.w.)	56.0 (72.0)	65.0 (60.0)	66.0 (60.0)	65.0 (59.0)	64.0 (60.0)
3.	Na^+ (μ eq/leaf)	61.0 (420.0)	290.0 (325.0)	420.0 (275.0)	480.0 (275.0)	645.0 (235.0)
4.	K^+ (μ eq/leaf)	24.0 (150.0)	81.0 (106.0)	57.0 (87.0)	48.0 (93.0)	45.0 (70.0)
5.	Cl^- (μ eq/leaf)	74.0 (415.0)	520.0 (290.0)	518.0 (270.0)	585.0 (260.0)	730.0 (250.0)

*1—Youngest, unopened, 2–4—maturing leaves; 5—senescent, f.w.=fresh weight.

Although absorption is facilitated by high negative pressure of the xylem sap, the plants conserve water by reducing the rate of transpiration. Values of rate of transpiration in case of some plants are given in Table 6.

TABLE 6

Rate of transpiration in some mangrove species
(After Stocker, 1956)

S. No.	Species	Average rate ($g/dc^2/day$)
1.	*Aegialitis annulata*	3.60
2.	*Aegiceras corniculatum*	1.80
3.	*Avicennia marina*	4.68
4.	*Rhizophora mucronata*	1.80
5.	*Sonneratia alba*	1.80
6.	*Lumnitzera littorea*	4.68
7.	Other Species of unstressed habitat	7.29–39.60

b) High ratio between Na^+ and K^+ ions in sea water, 40 : 1 on molar strength basis

According to Epstein (1965) potassium is such an essential element which is needed in almost the maximum amount out of all minerals taken from the substratum. As sodium, a chemically related ion with potassium, is found 40 times more in sea water can interfere with absorption of potassium. But this difficulty is offset by mangrove species as they have been found to have preferential absorption of potassium. It has been demonstrated that two different mechanisms operate for absorption of K, one at low concentration of K in the medium (up to 1.5 mM) and the other at high concentration of K (up to 50 mM).

Mechanism—1 has great affinity with K and the presence of high amount of Na does not interfere with its absorption, even when Na concentration becomes up to 100 mM, in case of most of the plants, even, barley.

Mechanism—2. Operating at higher concentration of K has less affinity with K and its absorption and transport are known to be interfered by Na at high concentration in most plants, including some crop plants like barley. But in mangroves, as shown in the case of leaves of *Avicennia marina* (Rains and Epstein, 1967), Mechanism 2 is not at all interfered by high concentration of Na, even at a concentration of 500 mM which is a concentration normal for sea water. This preferential absorption of K does not exclude Na altogether, which is also absorbed in substantial quantity but only helps to build up necessary concentration of K ion to reach from 40 : 1 (as in sea water) to 7 : 1 or so enabling normal growth and metabolic activity. *A. marina* seedling leaf contain 1.0 per cent K and 4.1 per cent Na on dry weight basis.

Preferential absorption of K^+ is one aspect of the physiological competence of mangroves but another aspect is the ability of their tissue to tolerate high concentration of Na without injury. Na is well known to cause injury to tissues in normal plants if absorbed in high amounts.

c) *Periodic inundation of habitat with saline water and subsequent exposure*

Periodic inundation with fresh sea water provides the chance of better oxygenated water for animals and plant roots but the lenticels of pneumatophore and other aerial roots are rendered functionless during inundation. But, as pointed out earlier, they are hydrophobic and do not pass water inward (Scholander et al., 1955). Thus they do not get clogged up with water and start functioning during exposure. Small animals living in narrow burrows plug their openings at the time of flooding and live, so to say, in an 'air bubble'.

During the inundation period mangroves on their inner fringe (towards the water source) suffer on account of part of their lower branches getting submerged in water and important metabolic functions such as photosynthesis (during day time) and respiration, come almost to a stand-still and the intercellular cavities may get clogged with water. But a recent study (Misra et al., 1984) indicates that, like pneumatophore, they might be hydrophobic because the leaves which face periodic submergence have been found to have much higher hydrophobic content, such as lipid, wax ester and hydrocarbons (Table 7). This obviously must be making them submergence-tolerant. As a consequence of the presence of a higher amount of hydrophobic content, the rate of water loss of such leaves to atmosphere, either when attached to the parent plant or in a detached condition is one-fourth to one-fifth of the normal emergent leaves (Table 7). Even the chlorophyll content of submerged leaves is 3 to 4 times higher, may be thereby, compensating the carbon assimilation setback during submergence. The periodic submergence instead of causing thinning off leaves, as expected like leaves of submerged aquatic plants, become a little thicker and of course, their sizes increase as is normal in submerged leaves of emergent hydrophytes. Thus mangroves have some adaptations to cope with the ill-effects of submergence in water periodically.

d) *Deficiency of nutrients*

The nutrient in mangrove substratum and surface water is poor in terms of combined nitrogen (Ryther and Dunstan, 1971). This deficiency is further accentuated by the export of particulate matter by tidal current, which in red mangrove forest of Puerto Rico was found to be 2.27 g/m^2/day (Golley, et al., 1962). This stress is made good by the following special features:

i) Washings from neighbouring forest or interior areas during floods in rainy season bring enough nutrients. This flooding not only brings nutrients but dilutes salinity to the advantages of mangroves, which show best development in 1.2 to 2.0 per cent salinity (Pannier, 1959; Macnae, 1968; Davis, 1940).

ii) Nitrogen deficiency in sea water and mangrove substrata is well documented. This deficiency has been found to be overcome by a high nitrogen-fixing activity in soils and roots of several mangrove and associated species from Tampa Bay region, Florida (Zuberer and Silver, 1978). This is expected to be true for other mangrove habitats as well. In Table 8 the nitrogen-fixing activity at Cockroch Bay of Tampa Bay region is given:

Gotto and Taylor (1976) also found similar activity in decaying leaves of *Rhizophorae mangle* (red mangrove) in Florida (Table 9). Fell et al. (1975) observed that red mangrove leaves lose significant portion of their nitrogenous compounds by leaching during the first few days of immersion in sea water but that this loss is later replenished by nitrogen fixation by microorganisms with decaying leaves.

Some leguminous species associated with mangroves, like *Derris* spp., and *Cynometra* spp., have been found to fix nitrogen, adding combined nitrogen to the habitat.

Most of the mangrove species have lenticular bark. It has been shown in the case of *Bruguiera gymnorhiza* (Uchino et al., 1984) that there are nitrogen fixing bacteria in the lenticular bark similar to that of *Ilex pedunculosa*, *Robinia pseudoacacia* and *Mallotus japonicus* (Yatazava et al., 1983). These nitrogen-fixing bacteria associated with warts, thus contribute to the nitrogen economy of the mangrove forest ecosystem, and value of this addi-

TABLE 7

Total lipid, wax esters, hydrocarbons, decrease in fresh weight (Mg cm^{-2} (2h)$^{-1}$, Change in leaf area, thickness and Chlorophyll contents of submerged and emergent leaves of some mangroves

Species condition	*Acanthus ilicifolius*		*Avicennia officinalis*		*Bruguiera gymnorhiza*	
	Emergent	Submerged	Emergent	Submerged	Emergent	Submerged
1. Total lipids	14.3±2.0	33.6±3.26	60.8±5.09	118.8±9.29	192.2±7.47	95·6±13.8
2. Wax esters	1.9±0.16	4.5±0.5	2.8±0.28	7.2±0.88	6.8±0.74	15.0± 1.18
3. Hydrocarbons	1.0±0.27	3.48±0.37	3.2±0.18	10.4±0.59	9.2±0.48	28.3± 2.74
4. Decrease in fresh weight	3.1 ±0.19 (2.96±0.11)	0.8 ±0.13 (0.5 ±0.08)	5.8±0.28 (4.0±0.16)	1.44±0.21 (1.6±0.08)	2.8±0.16 (5.8±0.16)	1.3± 0.1 (0.56± 0.09)
5. Leaf area (Cm^2)	43.4±0.5	72.9 ±0.83	46.5±1.07	51.8±0.86	81.3±0.88	85.6± 1.05
6. Leaf thickness (mm)	0.47±0.3	0.49±0.02	0.45±0.02	0.50±0.00	0.56±0.02	1.48± 0.02
7. Chlorophyll content (Mg Cm^{-2})	4.7 ±0.16	15.1±0.22	4.9 ±0.16	12.14±0.15	3.50±0.33	13.7±0.22

Figures in parentheses are values for detached leaf.

TABLE 8

Nitrogen fixing activity in Tampa Bay
(n mol of C_2H_2/wet/wt/hr)

Sample type	Rate of N_2 fixation
Anoxic sulphid mud	1.26
Mean low water sediment	0.25
Proproot associated sediment	0.35
Peaty sediment slurry	34.37
Litter material	17.35

TABLE 9

Rates of N_2 (C_2H_2) fixation associated with leaves of *R. mangle* at various stages of decay

Decay time in field (Days)	N_2 fixation (μg of N/g dry wt. per hour)
0	0.0
2	0.2–0.3
7	1.1
14	4.0–1.6
21	3.5–0.8
28	2.3–0.4

tion may be near 30 kg of N ha^{-1} year as in wet tropical forests. The bacteria strains in the lenticular bark have been found to belong to the family Enterobacteriaceae. Four strains of bacteria were isolated and two of them showed similarity with *Enterobacter clocae*, one to *E. aerogenes*, and the other with *Klebsiella pneumoniae* and may be some strains of the same.

e) *Anaerobic or near-anaerobic condition of habitat*

It has been well documented that muddy substrata of mangroves are anaerobic in a little deep horizons. Troll and Dragendorff (1931) showed that in the East African muddy shore in which *Sonneratia* roots were embedded was anaerobic. Root habitat of *Rhizophora* and *Avicennia* was also found by them to be oxygen-free except in the upper 5 cm soil layer and there must be lot of problems of respiration for underground parts, under normal condition. This is mitigated to a very large extent, due to production by mangroves of various types of aerial roots studded closely with lenticels. In pneumatophore of *Avicennia* number of lenticels per cm is about 9–10. When fully exposed to air they freely exchange oxygen and CO_2 with atmosphere. There are highly developed aerenchymatous tissue in pneumatophores and subterranean roots and oxygen exchanged in aerial roots freely reaches subterranean absorbing roots. Even corky outer tissues are pervious to air and add to exchange capacity when water recedes during low water level of spring as well as neap tides. Extensive aerenchyma in roots making them thick from the beginning form a very efficient system, since it increases the root surface without increase in quantity of respiring tissue (Williams and Barker, 1961).

Types of aerial roots in mangroves—to cope with anaerobic condition of habitat many mangroves produce aerial roots, studded with lenticels which have been found to be hydrophobic not permitting water to pass through for clogging the air passage. They are of the following types :

a) Vertical finger-like pneumatophore: They are normally 10–30 cm but may be twice as high. They do not branch normally but due to damage of the growing tip two to three vertical branches may be produced. All species of *Avicennia* produce such roots. The enormity of their number could be judged by noting that a 2–3 m tall sapling may have well over 2000 of them and neighbouring ones may be only 10–20 cm apart.

b) Erect conical pneumatophore—Species of *Sonneratia* have some what conical aerial roots > 30 cm high with thickened base which may have a diameter of 7–10 cm.

c) Vertical flat blade-like pneumatophores—*Xylocarpus granatum*, in muddy habitats, generally produce narrow, up to 5 cm wide, flat pneumatophores. Such pneumatophores have also been reported in *Heritiera fomes*.

d) Knee-like roots: The subterranean roots in almost all mangrove, run horizontally and do not go deep. These horizontal roots at places become negatively geotropic and emerge out of substratum and after reaching some height in the air again change geotropic behaviour and turn towards the ground forming a knee-like structure and at the bend the distal portion produce several branches which are positively geotropic. There is some vertical growth at the tip of the bend which may be cylindrical (*Bruguiera gymnorhiza*) or flattened, blade like (*B. parviflora*). Such roots are produced by all the species of *Bruguiera* and *Ceriops* where they grow in thickness. *Lumnitzera* spp. also produce such roots but they remain thin and are not very conspicuous as their heights are small.

e) Stilt and strut root: *Rhizophora* species produce from the base of stems (above hypocotyl) thick roots in early sapling stage and take a slow bend forming an arch and reach the ground at some distance. On reaching the ground they produce thick branches which in turn produce thin fibrous branches for absorbing water nutrients. Near-ground thicker branches are produced which an arch in the air and come to the ground forming an arch. Such looped roots are known as strut roots. Such extensive roots are produced particularly by plants on the inner fringe. It is these roots which make walking in mangroves very difficult.

f) Prop roots: In *Rhizophora* stem branches produce positively geotropic roots. They may arise even from great heights at 6 to 8 m or more. They remain unbranched till they touch the ground surface and after entering soil, branch profusely forming thicker as well as finer branches for absorption. Aerial portion branch after their tips are damaged by some agencies, mostly molluscs. They do not grow much in thickness and are full of lenticels. The stilt and prop roots of *Rhizophora* sometimes form very intricate aerial root system making walking well nigh impossible.

f) Functioning of mangroves

i) Productivity and photosynthesis: Mangroves are evergreen species but an estimate of their standing biomass and rate of production reveal that it is much less than those of typical tropical rain forests. It is primarily due to various stresses operative in their habitats mentioned earlier. The standing biomass, and rate of dry matter production is given in Table 10 for some types of vegetation. Though even in case of managed and well developed mangrove forests biomass and net annual production are lower than tropical rain forest (the highest type of vegetation) yet are more than that of good deciduous forests. At places due to local conditions some mangroves are poor in density, diversity and complexity index. Looking to the great stresses operating in mangrove habitats the productivity is good enough so as to provide plenty of food to huge populations of juveniles of fish, shrimps, molluscs, crustaceans and horde of other animals. It is on account of this that commercial fisheries are more successful in the vicinity of mangrove areas. It is estimated that commercial fisheries give more economic return than exploitation of the mangrove forests product.

Photosynthesis: Many halophytes have been shown to follow the C_4 pathway in photosynthesis (Shomer-Ilan et al., 1973, and Beer et al., 1976) without Kranz anatomy. Mangrove grass, *Aeluropus lagopoides* (Waghmode and Joshi, 1979) and seashore sand-binder, *Spinifex squarossus* (Das and Raghvendra, 1977) have been shown to have C_4 pathway. Joshi et al. (1976) concluded, on the basis of domination of aspartate in initial products of photosynthesis and through pulse chase study its utilization in synthesis of sugar, that many mangrove species follow the C_4 pathway. They have also shown a much greater abundance of PEP case as compared to RuBP case and the presence of pidikinase in several mangrove species (Joshi et al., 1980), which also suggests the presence of C_4 pathway in many mangroves.

However, the studies by Andrews and Clough (1980) on various aspects of photosynthesis in *Rhizophora* indicate its discrimination against ^{13}C. Fourteen other mangrove species of Australia also show their discrimination against ^{13}C thus showing that they follow the C_3 pathway.

ii) General remark: Mangroves form very special types of vegetation, protecting our seacoasts against erosion and work as buffers, reducing the

TABLE 10

Biomass and rate of dry matter production in mangrove and some other natural vegetation

Country	Vegetation type	Biomass (t/ha)	Rate of dry matter production (t/yr)	Authority
Europe	Spurce pine forest	80.0–330.0	7.0–14.0	Rodin & Bazilevich, 1967
USSR	Birch forest	220.0	12.0	,, ,,
USSR	Grassland	10.0– 25.0	4.0–14.0	,, ,,
India	Deciduous forest (Varanasi)	223.0	15.0	Deshbandhu, 1970
Africa	Tropical rain forest	500.0	32.0	Rodin & Bazilevich, 1967
Malaysia	Mangrove (Managed)	300.0	23.0	Eong et al., 1979

fury of violent storms and typhoons to the advantage of inland forests. Apart from these biophysiochemical processes in nature they provide raw materials useful to man. In spite of great stresses operating in their habitats it is quite remarkable that their rate of dry matter production is relatively high. Due to all these there is an urgent need for a more militant management and conservation of mangrove areas as total ecological unit. For proper management succession status of various species should be given due to consideration. *Avicennia alba*, *A. marina*, *Sonneratia alba*, *S. apetala* and *S. griffithii* and to some extent *Rhizophora* spp. are pioneers and need more light for their growth and development and while felling more plants can be cut at completion of growth cycle. *Bruguiera* spp. *Ceriops* spp. and *Xylocarpus* are shade-tolerant and at completion of the growth cycle good number of trees should be spared.

As a part of the conservation policy of mangroves freshwater diversions for some purposes should be avoided. Over exploitation should be given up. At several places, their reclamation for agriculture has proved a failure and such ventures should not be undertaken. Their cutting for industrial development should be stopped. Salt pond construction in Gujarat destroyed good areas of mangrove. Dumping of solid, liquid, including oil and other hazardous chemicals should be avoided.

With our continuous addition of waste salts in water resources as well as increasing contamination of underground water sources, there is a constant increase in salinization. This compels us to think that the future of plants lies with halophytes and we have to understand thoroughly their functioning so as to introduce these characters in our crop plants. This is very essential and would be in near future, a matter of 'life and death' to the growing population of a world whose water sources are becoming more saline (Waisel, 1972).

Our progress in science and technology, certainly is also in this important area. Some paddy varieties have been evolved which do well in brackish habitats. Thus science and technology will be able to solve this problem as well.

MAN-MADE STRESSED HABITS

Very fast industrialization has been a rule for most of the developing countries.

When a living system expands energy—rich raw material for growth and activity, it is axiomatic that a lower energy byproduct or waste material will result from the process, and no species or organisms can live on its own waste products. Thus all living organisms including human beings produce primary products, according to natural law, which can be called pollutant, which put the human environment out of balance but the scheme of nature is such that it will react so to re-establish a balance. In nature what is one organisms waste or poison is anothers food. This process of production of primary pollutants and re-establishment of balance continued before the age of industrialization. The latter was to improve the quality of living and according to Fitter (1970) there is a close relationship between the quality of living (q), utilization of resources (r) and population (p) as shown by him by the following equation:

$$q=\frac{r}{p^2}$$

Quality of living is directly proportional to resources used and inversely proportional to the square of population. To achieve a better quality of life and in the presence of fast increase in population, resources are being used at highly increased rate producing pollutants beyond nature's capacity to re-establish balance and habitats are getting stressed for normal life of plants and animals.

Stressed water system: A small river Khan, originating near Indore, an important industrial town of Madhya Pradesh, joins another river Kshipra after a flow of nearly 64 km, near Ujjain. When River Khan passes along Indore it receives effluents of the textile mills and sewage of the town. The amount of waste water received form different textile mills is given in Table 11.

TABLE 11

Daily discharge of waste water from 4 textile mills (iu m^3) and their BOD (mg/L)

Sl. No.	Name of the Mills	Amount of water discharged	BOD
1.	Hukumchand Mills	15,370	8,300
2.	Hope Textiles	3,150	1,316
3.	Kalyan Textiles	1,800	643
4.	Rajkumar Mills	900	363

The waste water is loaded with toxic chemicals, including dyes, detergents and bleaching agents. The dyes are rich in arsenic, cadmium, chromium, zinc, lead, copper and cobalt. These chemicals make the water system highly stressed for a biological system. A study of water quality at four sampling stations was done: (1) at the confluence of waste water nallah with River Khan, (2) at a distance of 10 km downstream, (3) at a distance of 30 km downstream, and (4) at a distance of 55 km downstream where water was almost normal. The results of this assessment are given in Table 12 (Rao et al., 1978).

The functioning of the ecosystem was assessed by primary productivity which was very much reduced at stations 1 and 2 (Rao et al., 1979) and is given in Table 13.

TABLE 12

Some chemical characteristics of water at the 4 stations (Average of 6 monthly data from September 1976 to September 1977)

Station No.	pH	Turbidity (cm) Secchi disk transparency	Dissolved O2 (mg/l)	Total dissolved solids (mg/l)	Total alkalinity (mg/l)	Chloride (mg/l)	Total sulphide (mg/l)	% 'Cl' + NO3	Total PO4 (mg/l)	BOC (mg/l)	BOD (mg/l)
1.	8.4	5	0.2	1500	78	75.00	0.5	24.5	0.44	380	120
2.	6.2	15	5.0	1350	89	124.11	0.4	13.8	0.56	300	115
3.	10.85	25	10.85	1152	64	74.00	1.6	10.5	0.35	74	32
4.	6.8	35	11.50	496	15.5	55.00	2.5	5.6	0.26	42	20.4

TABLE 13

Primary productivity and respiration at different stations (Carbon g $m^{-2}/6$ hr)

Months	Gross Nos.	Productivity at Station			Net Nos.	Productivity at Station			Respiration at Station Nos.			
	1	2	3	4	1	2	3	4	1	2	3	4
January	0.0038	0.53	0.60	1.58	0.0001	0.38	0.45	0.90	0.0037	0.16	0.51	0.68
March	Nil	0.75	0.37	0.75	Nil	0.29	0.85	0.38	Nil	0.46	0.52	0.38
May	Nil	0.38	0.90	1.05	Nil	0.230	0.41	0.45	Nil	0.15	0.49	0.60
July	Nil	0.19	3.19	—	Nil	0.15	0.15	—	Nil	0.04	0.04	—
September	Nil	—	—	0.30	Nil	—	—	0.23	Nil	—	—	0.97
November	Nil	0.90	1.03	0.96	Nil	0.53	0.51	0.59	Nil	0.37	0.49	9.37
Average (Monthly)	± Nil	0.55	0.61	0.93	± Nil	0.31	0.47	0.51	± Nil	0.24	0.41	0.42

Flagellates and blue green algae dominated the most polluted (stressed) stations 1 and 2. Diatoms and other green algae dominated stations 3 and 4.

Benthic macro-invertebrates also react to stress water conditions. At sampling station 1 tubificid worms like *Tubifex tubifex* and *Limnodrilus hoffmeisteri* formed 80 per cent of the population while they were only 10 per cent at other stations. Snails and insects were absent here. At station 2 chironimid larvae dominated. Snails, clams and insects were abundant at stations 3 and 4, where stress was very much reduced and almost normal conditions were restored due to the self-purification process.

Stressed water system in Chambal River: Nagda, a village up to year 1951 and situated at a distance of 55 km west of Ujjain became site for the establishment and development of a massive industrial complex known as by GRASIM (Gwalior Rayon and Silk Manufacturing Company Ltd. in 1951). It consists of five units (1) Viscose Rayon unit, (2) Chloralkali unit, (3) Sulphuric acid unit, (4) Carbon sulphide unit, and (5) Thermal Power Production unit. Their production capacity and waste-water produced is about 80,000 m^3 day (Trivedi, 1979) loaded with toxic elements such as mercury, zinc, acids, organic wastes is discharged into river Chambal daily resulting into complete denundation of life up to 17 km downstream (Trivedi, 1979). The water in this span was unfit for irrigation purposes and even harmful for drinking by cattle.

When the plant started working there was great hue and cry from the public and the authority started a plan of treating the waste water. After the first phase (1981–82) and the second phase of treatment plant (1984–85) a lot of improvement started as given in Table 14. Nagda can be said to be an example to show that industrial waste water could be treated before its disposal in some water resources and the treated water could be quite safe for many normal purposes even at the point of confluence.

Man-made stresses in soil system: Huge quantities of various types of pesticides are being used to eliminate weeds and other pests from crop plants. Their application shows improvement in crop yields but they persist in the soil for a longer time than the registered period. As their effect is species-specific they do harm to the next crop. Four herbicides were applied on groundnut. An assessment of the residual effect on the subsequent crop (Purohit et al., 1978), gram (*Cicer arietinum* L. var. JG 62–404) and wheat (*Triticum vulgare* L. var. Narbada 4) was made. The herbicides used in groundnut were Bladex, 2, 4-D, Prefix and Planavin in concentrations of 50, 250, 500 ppm. The result is given in Table 15. Marked adverse effect of germination of seed's was also noticed.

Scientific methods to undo the residual toxic effects: The residual effect of herbicides, viz. Asulox (1 ppm), Dalapon (1 ppm) and Planavin (1 ppm) was studied and efforts were made to see the effectiveness of urea+NA to undo the toxic effect. The result show that they improved the performance of *Zea mays* as given in Table 16.

TABLE 14

History of various physico-chemical characters of Chambal water, upstream and at the confluence of waste water during 1976–77 (before treatment plant), 1981–82 (1st phase of treatment plant) and 1984–85 (2nd phase of treatment)

Characteristics	Upstream	In 1976–77	In 1981–82	In 1984–85
1. BOD mg/l	8–10	280–340	150–180	5–20
2. COD ,,	25–30	600–650	400–500	40–80
3. DO ,,	8.5	0.0	0.0	20–3.0
4. 'SO4' ,,	20.0	900–1,100	400–500	150–270
5. T.S.S. ,,	85.0	300–350	200–240	25–60
6. T.D.S. ,,	132.00	3,000–3,250	2,000–2,500	1,800–2,000
7. Zinc ,,	—	13–14	7–9	0.5–0.01

B.O.D. = Bio-chemical oxygen demand, C.O.D. = Chemical oxygen demand.

D.O. = dissolved oxygen, T.S.S. = Total suspended solids. T.D.S. = Total dissolved solids.

TABLE 15

Growth performance of gram (G) and Wheat (W) in soils with herbicides residues

		Control		Concentration of herbicides in groundnut crop (ppm by wt.)											
Sl. No.	Observation parameters			50		250		500		50		250		500	
		G	W	G	W	G	W	G	W	G	W	G	W	G	W
1.	Shoot length (cm)	21.7	28.8	23.8	25.5	18.7	22.5	—	—	21.4	22.5	20.8	21.3	20.4	16.4
2.	Root length (cm)	24.8	16.7	15.2	12.1	14.8	8.8	—	—	10.9	13.7	10.7	12.9	8.1	9.1
3.	Shoot dry wt. (g)	0.58	0.32	0.81	0.27	0.56	0.16	—	—	0.64	0.32	0.58	0.27	0.22	0.16
4.	No. of nodules	3.4	—	—	—	—	—	—	—	—	—	—	—	—	—
				Planavin								Prefix			
1.	Shoot length (cm)	27.7	28.2	9.2	—	8.6	—	5.3	—	22.5	16.5	18.5	14.3	16.3	5.1
2.	Root length (cm)	24.8	16.7	6.6	—	5.4	—	4.2	—	12.2	9.7	11.1	8.6	10.6	1.4
3.	Shoot dry wt. (g)	0.58	0.39	0.15	—	0.08	—	0.02	—	0.44	0.09	0.32	0.05	0.24	0.03
4.	Dry wt. root (g)	0.16	0.18	0.11	—	0.07	—	0.01	—	0.09	0.02	0.06	0.01	0.04	0.01
5.	No nodules	3.4	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 16

Role of urea and NA in antagonising the herbicide toxicide toxicity (*Zea mays* var. G5, G5_2, and Chandan Fresh wt. % reduction (−) or increase (+) plant

Treatment	Fresh wt. %	Reduction or increase in var.	
	G 5	G 5_2 (−)	(+) Chandan
Asulox (1 ppm)	−14.59	−11.78	−43.14
Asulox + Urea + NA	+19.79	+70.86	+47.30
Dalpon (1 ppm)	−39.47	−3.62	−59.71
Dalapon + Urea + NA	−2.17	+25.95	−48.00
Planavin (1 phm)	−5.75	−3.07	−4.31
Planavin + Urea + NA	+16.71	+77.96	+38.67

Amendment of the soil with urea + NA also caused an increase in chlorophyll 'a' and chlorophyll 'b' content, thus antagonising the toxic effect of the herbicide.

Finally I want to make one observation. I, as a student of ecology feel highly gratified to find that people in general, of all walks of life, have become conscious of ecology. At the same time several expressions in papers and speeches, that the "ecology of a particular place is being degraded", is highly undesirable, as ecology is a science and there is no question of the degradation of this science. The writers and speakers merely mean the ecosystem or environment and none of these words is a synonym of ecology.

REFERENCES

Andrews, T.J. and B.F. Clough. Photosynthetic gas exchange and carbon isotope ratios of some mangroves in North Queensland. *Proc. Biology and Management of Mangrove Papua, New Guinea:* An Int. Symp., Univ. of Florida, Gainsville, 1980.

Atkinson, M.A., G.P. Findlay, A.B. Hope, M.G. Pitman, H.D.W. Saddler and K.R. West. Salt regulation in the mangroves *Rhizophora mucronata* Lam. and *Aegialitis annulata* R. Br. *Aust. J. Biol. Sc.* 20 : 589–599, 1967.

Beer, S., A. Shomer-Ilan and Y. Waisel. Salt stimulated phosphoenolpyruvate carboxylase in *Cakile maritima. Physiol. Plant.* 34: 293–295, 1976.

Das, V.S.R. and A.S. Raghvendra. Karanz leaf anatomy and C_4 dicarboxylic acid pathway of photosynthesis in *Spinifex squarossus. Indian J. Exp. Biol.* 15: 645–648, 1977.

Davis, H. Jr. *The Ecology and Geology Role of Mangrove in Florida.* Carn. Inst. Wash. Pbl. 32: 1940.

Epstein, E. Mineral Metabolism. In Bonner, J. and J.E. Varner. (eds.) *Plant Biochemistry.* Academic Press, New York and London, pp. 434–466, 1965.

Epstein, E. Dual pattern of ion absorption by plant cells and plants. *Nature* (Lond.) 212: 1324–1327, 1966.

Fell, J.W., R.C. Cefalu, I.M. Master and A.S. Tallman. Microbial activities in the mangrove (*Rhizophora mangle* L.) leaf detrital system. In: Walsh, G.E., S.C. Snedaker and H.J. Teas, (eds.). *Proc. Biol. and Management of Mangrove,* An Int. Symp., Univ. of Florida, Gainsville, 1975.

Fitter, R. Country side seven years after a symposium in Lond. *Nature*. 228: 403, 1970.

Golley, Frank, H.T. Odum and R.F. Wilson. The structure and metabolism of a Puerto Rican Red mangrove forest in May. *Ecology*. 43: 1–19, 1962.

Gotto, J.N. and B.F. Taylor. N_2 fixation associated with decaying leaves of the red mangrove (*R. mangle*). *Appl. Environ. Microbiol.* 31: 781–783, 1976.

Hickel, B. Contribution to knowledge of a xerophilic water plant. *Chamaegigas intrepedus* Dtr. from South West Africa. *Int. Rev. Gesamten Hydrobiol.* 53: 361-400, 1967.

Joshi, G.V. Studies in photosynthesis under saline condition. *Shivaji Univ. Journal*. Kolhapur, 1976.

Joshi, G.V., S.D. Sontankke and L.J. Bhosale. Photosynthesis in mangroves. *Proc. Symp. on Biol. and Management of Mangroves Papua, New Guinea*, 1980.

Levitt, J. *Responses of plants to environmental stress*. Vol. 1 (2nd ed.) Academic Press, pp. 497, 1980.

Macnae, W. 1968. A general account of fauna and flora of the mangrove swampo and forests in Ind. West Pacific region. *Adv. Mar. Biol.* b: 73–270, 1968.

Mall, L.P. Germination of seed of three common weeds of dry phase of low-lying lands. *Proc. Nat. Acad. Sci.* India 24B: 197–204, 1954.

Mall, L.P. Ecology of temporary pools during dry phase. Ph.D. thesis, University of Saugar, Saugar, 1955.

Mall, L.P. Ecology of temporary pool, during dry phase. 1 structure of soil and plant community. *J. Indian Bol. Soc.* 20: 139–163, 1961.

Mall, L.P. Habitat, plants and their indicator value. In: Maheshwari, P., B.M. Johri and V. Vasil, (eds.), pp. 193–199, 1962.

Misra, Suniti, A. Chowdhury, A. Ghosh and J. Dutta. The role of hydrophobic substances in leaves, in adaptation of plants to periodic submergence by tydal water in a mangrove ecosystem. *J. Ecol.*, 72: 621-625, 1984.

Moharir, S.K. Ecophysiological studies of *Crypsis aculeata* and *Trigonella occulta*. Ph. D. Thesis approved by Vikram Univ. Ujjain, M.P. India, 1979.

Pannier, F.P. El effects dez distintas concentraciones salinas sobre et desarrollo de *Rhizophora mangle* L. *Acta Cerit. Venez.* 10: 68–78, 1959.

Purohit, M., L.P. Mall and P.S. Dubey. Residual toxicity bioassay of a few herbicides. *J. Indian Bot. Soc.* 57: 305–308, 1978.

Rains, D.W. and E. Epstein. Preferent absorption of potassium by leaf tissue of the mangrove *Avicennia marina* an aspect of palophytic competence in coping with salt. *Aust. J. Biol. Sci.* 20; 847–857. 1967.

Rao, S.V.R. Impact of pollutants on the primary production of the flora of River Khan, Ph.D. Thesis approved by Vikram Univ., Ujjain, M.P. India, 1979.

Rao, S.V.R., V.P. Singh and L.P. Mall. Pollution studies of river Khan (Indore) India-1. Biol, assessment of pollution. *Water Research*. 12: 555–559, 1978.

Rao, S.V.R., V.P. Singh and L.P. Mall. The effect of sewage and industrial waste discharges on the primary production of a shallow turbulent river. *Water Research* 13: 1017–1021, 1979.

Ryther, J.H. and W.N. Dunstan. Nitrogen, phosphorus, and entrophic cation in the coastal marine environment. *Science* 171: 1008-1013, 1971.

SCOR/COE of IUCN. Global status of mangrove ecosystems. Paper No. 3, pp. 86, 1983.

Scholander, P.F. How mangrove desalinate sea water. *Physiol. Plant*. 21: 251–261, 1968.

Scholander, P.T., S.T. Scholander and I. Evan Dam. Gas exchange in roots of mangroves, *Amer. J. Bot.* 42: 92–98, 1955.

Scholander, P.F., H.T. Hammel, E.A. Hemmingsen and W. Grey. Salt balance in mangrove. *Pl. Physiol.* 37: 722–729, 1962.

Scholander, P.F., H.T. Hammel, E.D. Bradstreet and E.A. Hemmingsen. Sap. presure in Vas. plants. *Science.* 148: 339–346, 1965.

Shomer-Ilan, A., Neumann-Ganmore and Y. Waisel. The effect of sodium chloride on the balance between C_5 and C_4 carbon fixation pathway. *Physiol. Plant.* 9: 190–193, 1973.

Stocker, O. Die Abhangig Keit der Transpiration von der Urnwell factoren. In: Ruhland (ed.) *Ency. Pl. Physiol.* 3: 436–488, 1956.

Trivedi, R.C. Pollution studies of Chambal river due to Nagda Industrial Complex. Ph.D. Thesis approved, Vikram Univ. Ujjain (M.P.), 1979.

Troll, W. and D. Dragendorff. *Plants XIII*, p. 331, 1931.

Uchino, F., G.G. Hambali and M. Yatazawa. Nitrogen fixing bacteria from warty lenticellate bark of mangrove tree, *Bruguiera gymnorhiza* (L) *Lampk. Appl. Environ. Microbiol.* 35: 567–575, 1984.

Waghmode, A.P. and G.V. Joshi. Kranz leaf anatomy and C_4 dicarboxylic acid pathway of photosynthesis in *Aeluropus lagopoides* L. *Indian. J. Exp. Biol.* 17: 606–607, 1979.

Waisel, Y. Biology of halaphytes. Academic Press, N.Y. Lond. pp. 395, 1972.

Walter, H. The water economy and hydrature of plants. *Ann. Rev. Plant Physiol.* 6: 239–251, 1955.

West, R.C. Mangrove swamps of the Pacific coast of Colombia. *Ann. Amer. Geog. Asso.* 46: 48–121, 1956.

Williams, W.T. and D.A. Barker. The functional significance of aerenchyma in plants. *Symp. Soc. Esp. Biol.* 15: 132–144, 1961.

Yalazava, M., G.G. Hambali and F. Uchino. Nitrogen fixing activity in warty lenticellate tree bark. *Soil. Sci. Plant Nutr.* (Tokyo) 29: 285–294, 1983.

Zuberer, D.A. and W.S. Silver. Biological dinitrogen fixation (Acetylene reduction) associated with Florida mangrove. *Appl. Environ. Microbiol.* 35: 567–575, 1978.

9

Plant Research and World Agriculture

M.S. Swaminathan

Introduction

In historical terms, agriculture is a very recent human venture. It is only about 12,000 years ago that women probably started collecting wild plants and cultivating them, thereby, starting settled agriculture. Progress in the domestication of plants was rapid soon after human beings took to settled cultivation. This is clear from the fact that in recent centuries we have not been able to add any plant of significance to the list of domesticated plants. Even medicinal plants like those used in the ancient systems of medicine of China, India and many other countries of Asia as well as Africa and Latin America had been known for thousands of years, long before chemists discovered their active principles. Rapid improvement in productivity per units of land, water, and time however became possible only after the introduction of irrigation several centuries ago, the application of mineral fertilizers in the latter part of the last century and the rediscovery of Mendel's principles of heredity in the beginning of the present century.

Prior to World War II, the most significant yield enhancement technology was the exploitation of hybrid vigour as in the case of maize coupled with good soil fertility, plant health care, and land and water management. In addition to genetic improvement, irrigation, chemical application, mechanization, and rural infrastructure development such as roads, markets, and electrification helped to improve the productivity and profitability of major farming systems. However rapid increases in population after World War II triggered by advances in preventive and curative medicine completely altered the food situation in many developing countries. Several developing countries which were formerly exporting food grains became highly deficient and had to depend on food imports to feed their population. There was also an atmosphere of gloom and despair with regard to the potential of many densely populated countries of Asia becoming self-reliant in food.

The introduction of semi-dwarf, photo-insensitive and high yielding varieties of rice and wheat in the mid-sixties at the initiative of the International Rice Research Institute in the Philippines and the International Maize and Wheat Improvement Center in Mexico however changed the entire outlook on the production potential of tropical and subtropical agriculture. During the past 20 years, many countries in Asia such as Bangladesh, China, India, Indonesia, Pakistan, Philippines, and Sri Lanka increased their capacity to produce rice and/or wheat by a quantity far exceeding the production level achieved during the preceding 2,000 years. For example, Indonesia produced less than 10 million tons of milled rice in 1965 while it harvested nearly 26 million tons in 1984. India produced about 10 million tons of wheat in 1964 while it harvested about 46 million tons in 1985. China's progress in increasing food production in recent years has been phenomenal.

Thanks to genetic improvement of yield and quality coupled with advances in other areas of agricultural technology, developed countries have increased production and productivity in almost all crops of economic significance in an impressive manner since World War II. Consequently by the end of 1984, with the main exception of oilseeds, global supplies of most agricultural commodities were well in excess of demand. Progress, however, has not been even in different parts of the world. Africa is currently failing to keep food production ahead of population growth. Although in normal years overall production has been increasing in African countries, per caput production has fallen by an average of about 1 per cent per year or 10 per cent a decade since 1970. Population growth is still about 3 per cent a year in many countries. In 26 countries south of the Sahara per caput staple food consumption was lower in 1984 than it was in 1970.

Countries in Asia and Latin America are at present in somewhat of a better situation but the present mood of optimism in these continents can be shortlived. Population in Asia is also growing rapidly and its adverse impact will be much greater since the initial population levels in countries like China and India are already very high (Table 1). Land resources in Asia are also extremely limited and soil erosion is still a major problem in many regions. In contrast, Africa has 800 million ha of potentially arable land, of which only 170 million ha are currently used for agriculture (World Food Report 1985). Although a little more than one-fifth of the African continent receives dependable rainfall, there is a large untapped reservoir of wetlands awaiting proper utilization based on sound principles of ecology and economics (Table 2).

According to FAO, the cereal carryover stocks are likely to rise to 294 million tons by the end of 1984–85 season. This is 28 million tons higher than the previous year. World production of cereals including wheat and rice rose

TABLE 1

Population projections: 1980 to 2100 (population in millions)

Selected Countries	1950	1980	2000	2025	2050	2100	Total Fertility Rate-1982	Year in which NRR = 1
China	603	980	1,196	1,408	1,450	1,462	2.3	2000
India	362	687	994	1,309	1,513	1,632	4.8	2010
Indonesia	77	146	212	283	330	356	4.3	2010
Brazil	53	121	181	243	279	299	3.9	2010
Bangladesh	44	89	157	266	357	435	6.3	2035
Nigeria	41	85	169	329	471	594	6.9	2035
Pakistan	37	82	140	229	302	361	5.8	2035
Mexico	27	69	109	154	182	196	4.6	2010
Egypt	20	42	63	86	102	111	4.6	2015
Kenya	6	17	40	83	120	149	8.0	2030
Regions Developing Countries:								
Africa	223	479	903	1,646	2,297	2.802	6.4	2050
East Asia	587	1,061	1,312	1,542	1,573	1,596	2.3	2020
South Asia	695	1,387	2,164	3,125	3,810	4,172	4.9	2045
Latin America	164	356	535	732	856	921	4.1	2035
Sub-total[a]	1,670	3,298	4,884	6,941	8,400	9,463	4.2	2050
Developed Countries	834	1,137	1,263	1,357	1,380	1,407	1.9	2050
Total World	2,504	4,435	6,147	8,298	9,780	10,870	3.6	

[a]Regional figures do not add to "Developing Countries Sub-Total" due to rounding.

Source: 1950: UN Estimates, Other Years: 1984 World Bank estimates and projections.

TABLE 2

Wetland soils for rice production on three continents

Region	Area of wetland soils[1] (m/ha)	Rice area harvested[2] (m/ha)
South and Southeast Asia	121	90.3
Africa	203	4.9
Latin America	231	8.2

[1] Based on analysis of the FAO Soil Maps of the World by Sanchez and Buol (1984).
[2] FAO Production Yearbook for 1981.

by 8.5 per cent to 1,780 million tons during 1984. While these figures make us proud of our capacity to feed growing populations with the effective use of science and technology coupled with appropriate government policies, we have to take serious note of the growing disparities in production performance by the developed and developing countries on the one hand, and within the developing regions on the other. Further, there are serious problems of equitable distribution. Although, the world grain reserve now is of the order of 300 million tons, a minimum of 300 million people in the world are currently undernourished and malnourished. It is in this context that we have to discuss the role of plant research in world agriculture during the decades ahead.

I will like to deal with two major issues relating to economics and ecology which are of particular interest to molecular biologists.

Economic Sustainability of High Yield Technology

At the end of 1984, the price indices of the principal commodities exported by developing countries were 14 per cent below the levels prevalent during 1979–81. There is a steady decline in the prices received by farmers for the commodities they sell (Fig. 1), while there is no commensurate reduction in the prices of the inputs and other goods they have to buy. Consequently, the consumption of inputs like mineral fertilizer has been going down in most parts of the developing world (Table 3). When the supply of inputs, particularly nutrients, gets lowered, average yields per ha will also go down. In contrast, in population rich but land hungry developing countries, the only pathways open for maintaining food self-sufficiency are higher productivity and greater intensity of cropping. This has to be achieved without causing harm to the long term production potential of the soil. Plant breeders using conventional techniques have made a significant contribution to lowering the cost of production without a concurrent reduction in yield by introducing genes for multiple resistance to pests diseases, multiple tolerance to soil stresses and toxicities, and improved efficiency of utilization of the nutrients

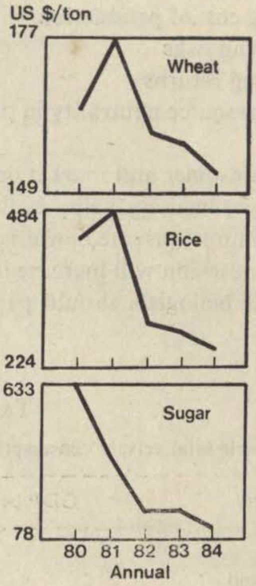


Fig. 1. International prices.

TABLE 3

Fertilizer consumption, total nutrients, by region 1971–80 and 1980–83

	Annual rate of change (%)	
	1971 to 1980	1980 to 1983
Developing Market Economies		
Africa	6.1	—
Far East	10.2	6.5
Latin America	9.9	−7.8
Near East	11.1	10.4
Asian CPE	12.4	6.0
Developing Countries	10.9	3.9
Developed Countries	3.6	1.3

Source: FAO

available in the soil. Agronomists and microbiologists are developing techniques and material for substituting market purchased inputs with farm grown inputs as well as for improving the efficiency of management of water and fertilizer. How can molecular biologists also help in the important task of promoting the economic sustainability of modern agriculture? The needs in this respect are:

1) increasing productivity
2) reducing cost of production
3) minimizing risks
4) enhancing returns
5) greater resource neutrality in the feasibility of adoption of new technologies
6) better consumer and market quality

Increased productivity helps both producers and consumers. Since the share of food in total private consumption expenditure is high in low income countries, malnutrition will increase if food prices are high (Table 4). Therefore, molecular biologists should particularly help in raising the ceiling to yield further.

TABLE 4

Share of food in total private consumption expenditure in selected countries, 1975

Country	GDP per capita ($US)	Share of food (per cent)
India	146	62
Thailand	359	45
Malaysia	780	37
Brazil	1149	35
Japan	4474	23
U.S.A.	7176	14

Source: FAO

1) RAISING THE CEILING TO YIELD

It is widely recognized by plant breeders that most of the advances which have taken place during the last 20 years in improving the yield potential of crops like wheat and rice have come from a higher harvest index (Table 5). Further increases of about 25 per cent may be possible from this source in several crops. Thereafter, yield improvement will depend on the ability to select for faster photosynthesis without reduction in leaf area. Unless photosynthetic efficiency can be improved by genetic engineering, further progress by plant breeders in raising yield potential, both per crop and per day, will remain dependent on agronomic innovations. The efficiency of photosynthesis could be improved if the genes determining the efficiency of light absorption, electron transport, protein pumping, and high energy phosphate bond synthesis in the chloroplasts can be reassembled from the best sources.

Depending upon the length of the carbon skeleton of the first product of assimilation, plants are classified as type C_3 or type C_4. The potential production rate of C_3 plants is around 200 kg dry matter per ha daily and of C_4 plants it is 200–400 kg, depending on the weather. Thus to arrange for C_3

TABLE 5

Biological yield, harvest index and grain yield (yield in tons per hectare)

Crop	BY	HI	GV
Rice			
Deep water rice	23.2	0.10	2.23
Tall *indica* (MTV)	6.13	0.39	2.39
Dwarf *indica* (TN–1)	9.00	0.56	5.03
Wheat			
Tall strains	11.04	0.24	2.92
Semi-dwarfs	12.54	0.39	4.89
Maize			
Varieties	15.2	0.24	3.7
Hybrids	15.5	0.44	6.8

plants to carry out C_4 metabolism would be highly useful. It could probably be achieved simply by having both kinds of chloroplasts in the same cell.

2) EXPLOITATION OF HYBRID VIGOUR

Heterosis has been a very important source of yield improvement in many crop plants. Even in a self-pollinated plant like rice, Chinese scientists and seed technologists have made it possible to cover over 8 million ha with hybrid rice during 1984. The development of hybrid rice in China became possible with the discovery of a male sterile plant from the wild rice, *O. sativa f. spontanea* on Hainan Island. In 1984 two rice hybrids, Wei-you 6 (V20A × IR26) and Wei-you 35 (V20A × Zhai-Shao), both having the same source of cytoplasmic male sterility, were grown over very large areas. While productivity has improved substantially, genetically homogenous crop strains are especially vulnerable to pest attack, as was highlighted by the 1970–71 outbreak of southern corn leaf blight due to *Cochlibolus heterostrophus* on all the U.S.A. maize hybrids carrying T-type cytoplasmic male sterility. A similar disaster took place in several parts of India in the early seventies when pearl millet (*Pennisetum typhoides*) hybrids, all having the same source of cytoplasm, were severely damaged by downy mildew disease. During 1985, a hybrid rice strain cultivated in over 1 million ha in the Sichuan Province of China was severely affected by blast in nearly one-third of the area. Genetic diversity of cytoplasmic factors is hence important. Recombinant DNA technology may help not only by eliminating unwanted genes from mitochondria but also by allowing the transfer of re-engineered mitochondrial cytoplasmic male sterile genes across sexual barriers. Protoplast fusion may also help to generate cytoplasmic variability.

Among the possible uses of tissue culture and genetic engineering techniques in hybrid rice improvement, the following merit priority consideration:

1) Expeditious transfer of CMS system(s) in different maintainer genotypes through protoplast fusion techniques.

2) Development of cybrids through protoplast fusion techniques. Cybrids may show some unusual behaviour not found in normal rices.

3) Understanding of molecular basis of cytoplasmic male sterility to identify and develop diverse and stable CMS sources.

4) Mass regeneration (through somatic embryogenesis) of somatic embryos from superior F_1 hybrids and their encapsulation for use as seeds in farmer's fields.

5) Mass multiplication of plantlets (through tissue culture) of superior F_1 hybrids as an alternative to bulk production of hybrid seeds.

3) ACCELERATING THE PACE OF PLANT BREEDING

Tissue culture techniques are already playing an important role in the following three areas:

1) Production of a large number of plants from a single superior plant much more quickly than is possible from seed multiplication;

2) Generation of disease-free plants from infected parents; and

3) Generation of plants difficult to propagate sexually.

Another immediately feasible opportunity is in the area of transferring genes across normal sexual barriers. The techniques available for this purpose include:

1) Embryo rescue;

2) Protoplast fusion followed by hybrid protoplast regeneration and differentiation; and

3) Use of DNA vectors such as Ti plasmids and other methods like micro-injection of DNA, etc.

Out of these techniques, embryo rescue through appropriate tissue culture techniques seems to be the most effective in the short term in higher plants. Under a Rockefeller Foundation–sponsored programme of genetic engineering in rice, IRRI proposes to take up a systematic study for the transfer of desirable genes from wild species of *Oryza* to commercially useful varieties (Table 6).

It should not be forgotten that while in unicellular organisms the modification of the cell is the end point of research, in higher plants, the modification of the cell is just the beginning of a long and often very difficult process of getting a whole plant from the altered cell and getting the altered gene expressed in the desired manner. Bacterial DNA contains about 5000 genes; a plant genome may contain between 5 million and 50 million of which less than 5 per cent may be actively synthesising protein at any one time. Hence,

TABLE 6

Wild species of *Oryza* with useful traits

Wild species	Useful trait
O. perennis	Tolerance to stagnant flooding and acid sulphate soils
O. nivara	Resistance to grassy stunt virus and blast
O. officinalis	Resistance to BPH, WMBPH and GLH
O. australiensis	Resistance to BPH and drought
O. barthii	Resistance to bacterial leaf blight
O. longistaminata	Floral characters for out pollination
O. coarctata	Tolerance to salinity

the transfer of genetic traits through DNA vectors is not simple. First the genes which express themselves in desirable characters in one plant have to be identified, isolated, excised, introduced into the vector, transferred into the plant whose characters are to be enhanced and then persuaded to turn on in that part of the plant where they are needed. In each plant organ: leaf, root, ovary, anther, a different set of specific genes express themselves. Furthermore, many essential plant characters result from the expression of several genes.

4) ANTHER CULTURE

Anther culture techniques involving the production of androgenic haploids and homozygous diploids through chromosome doubling have already established their utility in plant breeding. Chinese scientists belonging to the Crop Breeding and Culture Institute of the Chinese Academy of Agricultural Sciences have released several rice varieties through this method. The most recent among them is Zhong Hua 10 which was produced by culturing anthers from the cross Tetep/Nan 65. Two earlier varieties, Zhong Hua 8 and 9, have given outstanding performance and were recently given a High State Award. All these strains have a yield potential of 7–10 t ha^{-1}.

5) SOMACLONAL VARIATION

This technique presents opportunities for adding to the pool of genetic variability. Several salt tolerant genotypes have been reported in crops such as tobacco and pepper. There are however inherent limitations to this technique since only certain characters can be selected. Also, there is difficulty in distinguishing truly mutant cells from cells that have not changed genetically but have epigenetically adapted to the selection pressure applied. In both cases, the only solution is the screen at the whole plant level.

6) BIOLOGICAL PESTICIDES

Biological pesticides embrace naturally occurring or genetically restructured organisms that are specifically pathogenic to important pests, parasites or weeds. The potential spectrum of biological pesticides, which also include toxic substances of microbial or plant origin, is enormous and largely unexplored. Some of the larger agrochemical companies are seeking *in vitro* plant tissue culture techniques by which to isolate genotypes of cereals, other food and forage crops that are resistant to the herbicides they manufacture. However past experience shows that techniques which appear effective in the laboratory may give quite different results in farmers' fields. Also, the safety aspects of biological pesticides need careful consideration.

7) NITROGEN FIXATION

The potential for economically transferring nitrogen fixing genes from legumes to cereals appears rather remote. However, there may be immediate scope for producing improved strains of rhizobia by DNA transfer. Since this possibility is discussed more widely, I would like to draw attention to the need for greater research on the application of techniques of molecular biology to the improvement of green manure crops as well as biofertilizer sources like *Azolla* and blue green algae.

1) Improvement of green manure crops

The use of N_2-fixing leguminous crops as green manure could improve the fertility of thousands of ha of Asian and African soils, if the green crop used would: (a) be quick in growth, (b) fix considerable amounts of nitrogen during this period, and (c) release the nitrogen by mineralization processes relatively rapidly. The recently introduced stem- and root-nodulated leguminous crop *Sesbania rostrata* (Dreyfus and Dommergues 1980, 1981) may cover largely the demands mentioned above because it: (i) grows rapidly under flooded conditions, (ii) keeps on fixing nitrogen in numerous stem nodules (estimated at 200–250 kg/N/ha by micro-plot experiments at Dakar) within 40–50 days after emergence (=DAE), and (iii) becomes readily mineralized if chopped (Rinaudo et al. 1983). The fact that N_2-fixation is not suppressed when fertilized with mineral nitrogen (Dreyfus and Dommergues 1980) makes *S. rostrata* most attractive as it may help to accumulate N by repeated incorporation. All these properties make *S. rostrata* highly promising as a green manure to wetland rice. It can be easily introduced in the rice farming system (IRRI Annual Report 1983).

At IRRI, *Sesbania rostrata* accumulated 175 kg N ha^{-1} in 58 days when grown on an aerobic soil, and 150 kg N ha^{-1} when the soil was waterlogged from day 33 to day 58. When grown for 45 days on an aerobic soil, it accumulated 90 kg N ha^{-1}, and 70 kg N ha^{-1} when the soil was waterlogged from day 20 to day 45.

Rice grain yield response to the incorporation of *S. rostrata* grown under aerobic or partially waterlogged field conditions was as follows: 1. 3 and 2. 1

t ha^{-1} for 45 and 58 day crops grown aerobically, and 0.4 and 1.0 t ha^{-1} for 45 and 58 day crop with fields flooded during the last 25 days.

The tolerance of *S. rostrata* to waterlogging, and its ability to continue to fix nitrogen under waterlogged conditions, make this species a useful early wet season green manure in monsoon Asia. Its capacity to fix nitrogen however, exceeds the N needs of wet season rice crops in environments where low solar radiation and warm temperatures limit yield to 5 t ha^{-1} or less.

The potential nitrogen fixing ability of *S. rostrata* could be used more effectively if it were not photoperiod sensitive and would accumulate 150–200 kg N ha^{-1} when grown in November, December, or January prior to dry season rice. The green manure could be planted into wet stubble fields at the end of the wet season.

Can modern plant biotechnology methods help to achieve the following?

a) Eliminate photoperiod sensitivity or alter the plant so that the critical day length is less than 11 hours.

b) Introduce the strong stem nodulating habit of *S. rostrata* into other legume species which remain vegetative during short days but which are damaged when the root system is temporarily waterlogged.

2) *Improvement of biofertilizer sources*

a) *Azolla*: Sensitivity of *Azolla* to pests, and high temperature, and its requirement for high amounts of phosphorus are the major constraints for the growth of *Azolla* in field conditions in the tropics. The genetic diversity of *Azolla* in the germplasm collection at IRRI indicates that *Azolla* strains may vary in characters such as their demand for phosphate, ability to withstand high and low temperatures, and capacity to produce sporocarps. Since there is a symbiotic relationship between two partners, any screening and breeding (gene transfer) work probably can only be performed if they can be grown first in isolation and subsequently made to reunite. Unfortunately, unlike other symbiotic systems (like Legume-*Rhizobium* symbiosis), Koch's postulates have not yet been fulfilled in *Azolla–Anabaena* symbiosis. Furthermore, *Azolla* mostly reproduces vegetatively. Sexual reproduction is restricted to a few species and strains of *Azolla*, that too only under certain environmental conditions (e.g., low temperature). Not much work has been done on factors which could trigger sporulation and sexual reproduction.

Transfer of genes among different strains and species of *Azolla* through hybridization or by protoplast fusion will be very useful. A few strains of *Azolla* such as *A. filiculoides*, *A. microphylla* and *A. mexicana* have the capability to readily produce sporocarps under a wider range of environments and could be good material for mutation and gene transfer. The characters urgently needed are resistance to high temperature and to pests and the ability to grow in low phosphorus soils. Intraspecific hybridization through sporocarps might not pose problems for the symbiont *Anabaena* because its association is always maintained throughout the life cycle of *Azolla*.

Azolla floats on water, and insufficient phosphorus is often found in the floodwater. *Azolla* roots are not long enough to reach the soil to take up soil phosphorus. It might be useful to produce genetic variants of *Azolla* which can produce long roots capable of taking up soil phosphorus efficiently.

b) *Blue green algae*: Among the nitrogen fixing micro-organisms, only blue green algae (BGA) can generate photosynthate from CO_2 and water. This trophic independence makes BGA especially attractive as a biofertilizer in wetland soils. However, BGA are currently not used to a noticeable extent in rice cultivation because of the lack of a reliable technology and the moderate potential of BGA for increasing rice yield (Roger and Watanabe 1985).

One can speculate on the possibility of selecting or designing strains more efficient in fixing nitrogen. The physiological characteristics of nitrogen–fixation desirable for strains suitable for field inoculation were accurately described by Stewart et al. (1979). Such strains should: (1) be capable of rapid growth, (2) fix nitrogen equally well under aerobic, microaerobic, and anaerobic conditions, (3) fix nitrogen under photoautotrophic, photoheterotrophic, and chemoheterotrophic conditions, (4) evolve no or little hydrogen (whose production leads to a wastage of ATP and reductants), (5) possess a nonrepressible nitrogenase, and (6) liberate extracellular nitrogen in substantial amounts and in a form readily assimilable by the rice plant.

A major limiting factor for the growth of BGA is predation by populations of invertebrates such as snails or microcrustaceans. There is evidence that some BGA are more resistant to predation than others. Selecting or creating strains combining a high nitrogen fixing potential and resistance to grazing is another urgent need.

No doubt that such "superstrains" can be designed and grown in test tubes, but their designing is meaningless unless they can survive, develop, and fix nitrogen as programmed in rice fields. There is evidence that inoculated BGA rarely get established in the field and virtually nothing is known of the attributes permitting inoculated strains to colonize the various hostile environments to which they will be exposed (Gibson 1981).

Currently, microbial engineering has had some success in selecting or engineering, for industrial purposes, strains having special features such as a high production of useful chemicals. These strains function under specific and controlled conditions in a bioreactor. When looking for field use of bacteria or algal strains, competitions and the complexity of environmental conditions are major factors that could frequently limit the growth of non-indigenous inoculated strains as well as the utilization of genetically engineered strains.

8) IN VITRO SELECTION FOR SPECIFIC CHARACTERS

This is again an area of research with immense potential. Also during the past few years, the rapid screening of proteins by polyacrylamide and starch gel electrophoresis has been used in screening germplasm for genetic distinctness. Now genetic differences can also be detected by studying DNA sequences. For example, Flavell et al. (1983) have shown how repeated DNA sequence can be used as probes for detecting DNA incorporated from one species into another.

Ecological Sustainability of High Yield Technology

The various application in this area include the following:

1) Conservation of genetic resources;
2) Genetic evaluation and utilization;
3) Reducing risks from pests, pathogens, and weeds;
4) Scientific land use; and
5) Minimizing pollution hazards.

I shall briefly refer to a few aspects:

1) Germplasm Conservation at Molecular Level

There is urgent need for the development of techniques for germplasm conservation in the molecular level. The importance of germplasm collection and conservation in plant and animal breeding cannot be overemphasized. Recombinant DNA procedures allow cloning of any foreign DNA into *Escherichia coli*, and research is making this possible in yeast and other organisms as well. The technology is bound to become more efficient. Hence, cloned DNA and material having DNA in its native state can all be used for genetic conservation from now on.

Non-viable material representing valuable genotypes stored in gene banks need not be discarded. They could become sources for DNA libraries from where a relevant gene or combination of genes can be recovered. Thus, today, an integrated genetic conservation strategy can be planned at the level of populations, individuals, tissues and organs, cells, and DNA libraries.

2) Application of Monoclonal Antibodies

Since the hybridoma techniques was developed in 1975, monoclonal antibodies has been widely applied in medical sciences. However, monoclonal antibody production has been adapted to the field of plant sciences only recently.

Monoclonal antibodies have been used in plant virology for differentiation of strains, studying relationships to other viruses, diagnosis of virus infection, and analysis of antigenic protein structures. Monoclonal antibodies have been produced in the case of the following plant viruses:

Alfalfa mosaic
Apple mosaic
Arabis mosaic
Barley yellow dwarf
Potato Y
Potato X
Prunus necrotic ringspot
Rice dwarf

Carnation etched ring
Citrus leaf rugose
Citrus tristeza
Lettuce mosaic
Potato leaf roll
Potato A
Southern bean mosaic
Soybean mosaic
Tobacco mosaic
Tobacco streak
Tomato ringspot
Tulip breaking

Monoclonal antibodies have been applied to bacteria, to identify strains and to differentiate the bacteria from other pathogens. The bacteria for which monoclonal antibodies have been applied are:

Xanthomonas campestris pv. *campestris* (bacterial black rot of crucifers)
Spiroplasma citri (citrus stubborn disease agent)
Corynebacterium sepedonicum (bacterial ring rot of potato)

The development of diagnostic tools would help in early disease identification and epidemeological studies. We should also strengthen research on the precise identification of genes involved in disease resistance. They could then be used as molecular workers in breeding work. We also need work on Restriction Fragment Length Polymorphism (RFLP) mapping so as to produce molecular linkage maps of major crop plants. This will help in the early identification of promising seedlings.

Conclusion

We are currently very optimistic about what can be accomplished through biotechnology research in terms of practical achievements in agriculture. Some of the optimism is justified but we need a good deal of basic knowledge using conventional techniques before we can fully exploit the potential of molecular genetics in crop improvement.

First, we must gather more knowledge on how the cells of major crop plants can be handled in culture using an effective vector system with which we can incorporate foreign DNA. Secondly, while we have fairly detailed information on the inheritance pattern of economically important characters in the major crop species, the gap in our understanding of the metabolic processes between the gene and the final phenotype is great. Considerable gaps in our knowledge of plant biochemistry also need to be filled before we can use techniques of molecular genetics in a planned and purposeful manner. Thirdly, we have to learn "to labour and to wait" in this area of research. Past experience has shown that there is always a time lag between an original discovery and its final application. We should not therefore be impatient if we do not obtain results of practical value immediately.

Dr. R.B. Flavell of the Cambridge Plant Breeding Institute has compared progress in recombinant DNA technology with the time taken for the development of the wheat variety, Avalon. His analysis shows that over the period Avalon was developed, the whole process of changing DNA, learning how to incorporate that DNA in plant cells and to have it expressed was invented.

Coming to the relative priority to be accorded to the new techniques, let me deal with the approach of an applied research centre like the one where I work. At IRRI, scientists spend time finding solutions to well defined problems rather than just worshipping specific disciplines or tools of research. For this purpose, all tools and techniques that can help to achieve the desired research goals speedily and surely are harnessed. How can we identify which tools in the emerging areas of technology would help us in reaching our research goals economically and speedily?

The first task is to ask ourselves why and how the already available tools are inadequate or inefficient for solving the research problems we wish to solve. Secondly, we should ask ourselves whether the new tools of biotechnology like genetic engineering, tissue culture applications, etc., can help us to accomplish certain research tasks better than without them. Thirdly, we should identify areas of research where a suitable blend of traditional and emerging technologies can help us to add an additional dimension to our research capability.

While dealing with new technologies, we should always remember that in several cases their full potential may yet be unknown. For example, tissue culture research has been referred to by some experts as a "botanical laser" whose numerous uses are yet to be fully understood. Hence, there is need for much ingenuity, innovation, and patience while working with the new techniques.

An innovative integration of the tools of Mendelian and Molecular biology would help to accelerate progress in the development and spread of economically and ecologically sustainable food production systems. Building an enduring global nutrition security system will then become an achievable task.

REFERENCES

Annual Report of the International Rice Research Institute (IRRI). Growth and nitrogen fixation by two *Sesbania* species under different flooding densities. Cropping Systems Program. IRRI Los Banos, Laguna, Philippines, 1983.

Dreyfus, B. and Y.R. Dommergues. Non-inhibition de la fixation d'azote atmospherique chez une legumineuse a nodules caulinaires *Sesbania rostrata*. *C.R. Acad. Sci.* (Paris) 291: 767–770, 1980.

Dreyfus, B. and Y.R. Dommergues. Nitrogen fixing nodules induced by *Rhizobium* on the stem of the tropical legume *S. rostrata*. *FEMS Letters*. 10: 313–317, 1981.

Flavell, R.B., R.J. Kemble, R.E. Gunn, A. Abbott and D. Baulcombe. Application of molecular biology in plant breeding: the detection of genetic variation and viral pathogens. In: *Better Crops for Food.* London: Ciba Foundation. pp. 198–209, 1983.

Food and Agriculture Organization World Food Report. FAO Rome. pp. 73, 1985.

Gibson, A.H. Some inputs from basic studies to applied nitrogen fixation research. In: *Current Perspectives in Nitrogen Fixation*, A. Gibson and W.E. Newton (eds.), Australian Academy of Sciences. pp. 6–7, 1981.

International Development Research Centre. Biotechnology: Opportunities and Constraints. In: *IDRC Manuscript Report 110e*. International Development Research Centre, Ottawa, 162 pp. 1985.

McNamara, R.S. *The population problem: time bomb or myth*. World Bank, Washington. pp. 28, 1984.

Rinaudo, G., B. Dreyfus and R.Y. Dommergues. *Sesbania rostrata* green manure and the nitrogen content of rice crop and soil. *Soil Biol. Biochem.* 15: 111–113, 1983.

Roger, P.A. and I. Watanabe. Technologies for utilizing biological nitrogen fixation in wetland rice fields: potentialities, current usage, and limiting factors. *Fert. Rev. Special Volume*, 1985 (in press).

Stewart, W.D.P., P. Rowell, J.K. Ladha and M.J.A.M. Sampaio. Blue-green algae (cyanobacteria)—some aspects related to their role as source of fixed nitrogen in paddy soils In: *Nitrogen and Rice*, The International Rice Research Institute, Los Banos, Philippines. pp. 263–285, 1979.

Swaminathan, M.S. Agricultural production. *Lancet*. Dec 8, 1984, pp. 1329–1332, 1984.

10

Tropical Forests, Environment and Development

M.K. Muthoo

Ann poshi tele yele poshi van is an old adage from Kashmir that means food will last so long as forests do. Signifying the close relationship between forestry, environment and food production, Prime Minister Rajiv Gandhi declared on the occasion of FAO's World Food Day in October 1985 that "the agriculture battle will be won only if we safeguard the environment. Attention to food must go hand in hand with attention to fuel and forests." This is important in order to let development go forward as an ongoing process, for depletion and mismanagement of forest cover are already affecting human habitat, creating fuelwood famine, despoiling watersheds, increasing the recurrence and virulence of floods and droughts, enhancing desertification, reducing soil fertility, and degrading the productivity of land.

This paper presents a global overview regarding tropical deforestation and forest conservation vis-a-vis environmental management and socio-economic development in the Third World. It argues that tropical deforestation and related environmental degradation are closely linked to rural poverty and inappropriate policies. Harmonization of the principles of ecology and economics are warranted to ensure accelerated development without destruction. That needs enlightened leadership for promoting national action programmes and international cooperation involving increased investment and improved know-how.

Unless this happens, the tropical forests of the world will continue to be destroyed. These are being depleted at an alarming rate of over 11 million ha per year. Tropical deforestation is endangering the environment and the livelihood of millions of poor people. It is threateuing the existence of unique genetic resources and the supply of tropical timber and other valuable forest products.

Rampant deforestation, in both humid and arid areas, desert creep and concomitant environmental deterioration are symbolic of a social problem, calling for more than merely technocratic solutions. It is a problem stemming from population pressure, landlessness and rural poverty with vast numbers eking out their existence by deriving whatever they can from the forest land, be that food and fuel for themselves and fodder for their livestock.

This perpetuates the vicious circle of poverty, over-exploitation, deforestation, low productivity and more poverty, aggravated by rising population pressure, which is expected to increase in the years to come. FAO estimates that even if crop yields on land already cultivated would increase by 72 per cent, another 200 million ha would have to be cleared by the beginning of the next century.

Already around 5 million ha are annually opened up for new settlements. About 75 per cent of these are unplanned and spontaneously occupied by the landless, mostly in the semi-arid and humid tropical areas of the Third World classified as forest land and often characterized by fragile ecosystems. This results in destruction of valuable forest resources and quick depletion of the thin mantle of top-soil. Disillusioned by the rapid decline in productivity, the spontaneous settlers keep on moving in search of the elusive Eldorado. Similarly, growing numbers of people, about 200 million today, barely subsist by practising slash-and-burn agriculture over forest lands which no longer have the carrying capacity required for this form of land use. The fallow period in shifting cultivation is now generally too short to allow the soil to recuperate so that the precarious ecological balance in the forest land/man schema is upset irrecoverably and deleteriously.

Urgent need exists for increased harmony with ecological principles duly reconciled with increases in production and productivity of the rural poor. This calls for reformulation of forestry strategies and forest policies. These should be directed at overall development, integrating precepts of sound environmental management and permanence of the forest resource base in order to secure optimum flow of benefits for the present and future generations, including an equitable participation of the rural people in forestry and forest-based industries.

In general, and for too long, tropical forestry has not received the policy attention and resources that it deserves. Consequently, tropical forests have either been unmanaged or mismanaged. In some areas they have been under-utilized and mined for creaming the few commercially exportable species; in others they have been plundered and ravaged. Little has been done to valorize the resource base as a source of perennial income, without which the maintenance of large areas under forest cover is difficult to justify in the face of land hunger and mass poverty.

On the contrary, the practices that are followed in many areas rapidly destroy the forest and land resource base on which the livelihood of a considerable proportion of the world's population depends. As a result of the failure to implement suitable silvicultural and management methods, the myth has been spread that tropical forests cannot be utilized without deterioration of the various sites and ecosystems. This is despite the fact that tropical forests can be managed scientifically both in the interests of present and of future generations. In managing these forests scientifically and productively, the protective aspects of the forests can be conserved. The utilization of such forests can contribute, significantly, to economic development and to enhancing the quality of life of the peoples of the Third World.

The Third World is richly endowed with forests, but less than half are used and sparingly at that. Obviously, an enormous potential remains untapped. At the same time, forests are the Third World's green gold, representing capital stocks, readily mobilizable for energizing economic growth.

This need not be at the cost of depriving future generations, for forests are renewable and, by realizing the annual interest or growth, the capital is left intact. Unlike minerals and other natural wealth, forest growing stock is replenished, and even improved upon, through use. Furthermore, usage can be manipulated to suit desired levels and patterns of sustainable production. This provides a basis for continuing economic activity within wide margins of intensity made to match emerging demand-supply trends and to observe evolving ecological constraints.

Man-made forests yield high volumes of homogeneous material, thereby complementing and extending the role of natural tropical forests, which are suited to supplying large-size logs and high-value hardwoods. The tropical climate in the Third World is highly conducive to creating fast-growing man-made forests. These yield poles, fuel and pulpwood in five to 15 years, and logs in 20 to 80 years. By contrast, the corresponding years in the industrialized countries are 20 to 40, and 50 to 150 respectively.

Tropical forest plantations utilize efficiently low-productive land, such as the vast savannahs. They contribute to amelioration of the environment, halting of the desert creep, enrichment of the soil, and improvement of agricultural yields through appropriate choice of species and silvicultural systems. Agroforestry is a valid land-use option, especially on marginal lands, for combining crops on an ecologically viable basis, at the same time augmenting local incomes and eliciting people's participation in the production of food, fodder, fuel and timber.

The role of tropical forestry is most significant as regards to its contribution to the energy supply, particularly for rural communities. The consumption of fuelwood in the Third World is of the order of 1.5 billion cu m. This contribution may be valued at around U.S. $ 70 billion annually. Plantations aimed at supplying fuelwood help manifold in the cause of environmental conservation by taking pressure off traditional sources, by averting depletion of ecologically fragile vegetal cover, and by minimizing the use of materials of high manure value to farms. Fuelwood deficit in many tropical areas is a major problem to be overcome in solving the energy shortages of millions afflicted by it. Innovative measures are warranted in establishing man-made forests and simultaneously reclaiming wasted lands, evoking people's participation, and improving fuelwood production and utilization for better nutritional standards and for fueling local industries.

Both the natural and man-made forests in the tropics offer challenging prospects for promoting industrialization, diversifying trade and improving the balance of payments. The annual production of processed wood products in the tropics, including sawnwood, panels and paper, is of the order of U.S. $ 30 billion. The processing capacity can be expanded still further because of the presently low consumption in the Third World, which depends on imports for some 25 per cent of their consumption of paper, 15 per cent of pulp, and remains a net importer of wood-based panel products whose consumption is increasing at an annual rate of around 3 per cent.

The demand for wood and wood products will continue to expand in the years to come. Sought-after tropical timbers and fast-growing plantations, among other things, confer comparative advantage to the Third World. Although in recent years there have been fluctuations in the world prices for various types of forest products, these fluctuations have been far less pronounced for wood and wood products than for other tropical commodities. The relative stability, and long-term upward trend, of forest product prices is another advantage in establishing industries based on tropical forests.

These industries can save and earn foreign exchange, reduce unemployment, and assist in the equitable distribution of income and of economic activity. These industries tend to be located in the rural hinterland, in and around forested areas, with positive backward and forward linkages. Due to the wide range and types of forest industries, the industry demands varying intensities of capital, labour and skills; sawmilling can be labour intensive, and the pulp and paper industry is capital intensive. Appropriate technology germane to small and medium scale units is usually economically applicable. Capacity can be increased and sophisticated technology used as conditions become favourable. With scope for growth by degrees, tropical forest industries can pioneer and foster industrialization as well as introduce the local population progressively to sophisticated levels of technology.

It is yet another myth to say that forest industries are pernicious from an environmental viewpoint. Logging damage may be no more than leaving a forest to stagnate in senility. The cause of tropical deforestation cannot be attributed to scientific logging and management, but is primarily due to the indiscriminate felling for fuel, slash-and-burn agriculture, and spontaneous settlements. Emphasis needs to be put on the fact that forest production and processing need not destroy the forest. On the contrary, industrialization of the tropical forests promotes the valorization of the forest resource, which is the best guarantee for its conservation.

Tropical forestry and forest industries could frontally attack the Third World's pressing problem of poverty and ensuing environmental deterioration. But the Third World is deriving only a fraction of the potential benefits. There is little industrialization or modern intensive production, including man-made forestry. Technology is at hand to remedy the situation but institutional impediments are many, including the lack of appropriate policies, trained human resources, and organizational arrangements. Such constraints must be loosened and large scale investment made for realizing the tropical forestry potential, otherwise the Third World will be left holding a bagful of resources with dwindling value. For investible resources will get directed to other areas of production, including those substituting forest products.

As such, and in spite of forestry's role as a foster-mother of agriculture, the traditional urge to banefully encroach upon the tropical forest land prevails. Harmonization of conflicts in land use would be required to maximize forestry's complementarity to agriculture and to meet competing claims on land holistically.

A systems approach is needed, with attention focussed on the inter-disciplinary nature of the problem of planning tropical forest and related renewable natural resource use for socio-economic development. The disciplines involved are: (1) ecology, for bio-technical assessment of the use possibility of a resource base; (2) sociology, for considering the social, cultural and institutional constraints in an area; and (3) economics, for evaluating and ranking the uses in an order of priority for meeting developmental aims. The integration of the three disciplines for the preparation of an optimal plan can be achieved by systems analysis so that a rational plan will be the product of integrated analyses of the limiting roles of socio-cultural, ecological, and economic factors in a total environmental context, in which national and regional developmental aims and relationships with other sectors are taken into account.

Such an approach would recognize that in the economy of nature, forests are of utmost importance. Their sheer size is staggering, covering over one quarter of the Third World. Tropical forests comprise the greatest live storehouse of plants and animals with unrivalled variety and activity. They perpetually purify the air, convert solar energy into usable vegetable and plant matter, and serve as fresh-water reservoirs, all in vast amounts and without human effort.

Indeed, tropical forests are weighty elements of the ecological balance. By harnessing them judiciously through appropriate management, industrialization and conservation, tropical forestry is uniquely equipped to handle problems of ecology and development in a mutually compatible manner. That should alleviate the problems of deforestation, desertification, and environmental degradation, and of timber scarcity including fuelwood as a renewable energy resource.

11

The Structure, Dynamics, and Rehabilitation of Drastically Disturbed Ecosystems

Mohan K. Wali

"All things by immortal power
Near or far
Hiddenly
To each other, linked are,
That thou canst not stir a flower
Without troubling a star."
Francis Thompson (ca. 1897)

Introduction

Philosophers and poets possess rare insights. They read the present with uncanny ability, sharply focussing their eyes on the future. They visualized the interconnectedness of nature, as Frances Thompson did, well before any professional ecologists arrived on the scene. Historians, on the other hand, read backwards, i.e., they analyse the past. Ecologists read the present from the past and produce constructs that may predict future events. It is no wonder, therefore, that many ancient sages have recently been re-christened as "ecologists". Kautilya's *Arthasastra* (*ca.* 321–296 B.C.) contains the first reference to a land-use classification system in relation to landforms, soils, precipitation, and the prevailing agrarian use of the time (Bhattacharya 1978). Varahamihira's work (505–587 A.D.) contains methodical use of plants and termites as indicators of groundwater resources, and has earned him the title of "first ecologist" (Prasad 1980).

All through time, Alfred North Whitehead's (1929) "three-fold urge" of organisms as they live in their environment, has remained unchanged: (1) to live, (2) to live well, and (3) to live better. Proper ecological understanding of the structure, function and constraints of ecosystems is the backbone for attaining this "three-fold urge". Despite rich historical diversity and scholarship in the developing countries, ecological studies have not fared well in the recent past. Again, the Indian example: over two decades ago, the need for ecological studies in the Himalayas was stressed by Singh and Wali (1962, 1963). Tiagi and Gopal (1978) lamented the lack of a strong curriculum in ecological and environmental sciences in India's institutions of higher learning. Ramakrishnan (1978) emphasized a prime research need: "We know very little about [primary production] of the Indian forests; needless to add that our knowledge of the consumer and decomposer components and associated secondary production and decomposition processes is even more meagre." The reasons for this attitudinal turn-around in history are complex and beyond the scope of this paper.

The irony of the situation becomes clear when one realizes that the countries that are least ecologically-conscious also have the largest human populations, and a paucity of natural resources coupled with the greatest need for them. Food, space and shelter are the three mainstays of human welfare; their study is fundamental to the science of ecology. I shall deal here with some aspects of resource degradation and mitigation. As should be expected, I shall address my remarks in reference to their implications for India.

Nature of Disturbances

An ecosystem disturbance may be defined as an event or a series of events that results in altering the relationships of organisms and their habitats from their natural state, both spatially and temporally. The degree of anthropogenic disturbance is directly proportional to the needed restorative efforts. Where the disturbance is severe or drastic and the restoration requirements minimal or lacking, permanent loss of habitats and species-complexes result. Disturbances may be classed as drastic when they are created by such natural causes as volcanic eruptions and large-scale earthquake activity. Examples of man-made drastic disturbances are massive urbanization and large transportation corridors, as is surface mining for coal and other minerals.

Some perspectives on land-use changes vis-a-vis agriculture, urbanization and transportation, dams and reservoirs, mining, and waste generation and disposal have been given in Wali and Burgess (1985). Because of their intricate interrelationships, few components of the ecosystems can be replaced or substituted. Thus, like many ecologists, Ehrlich and Mooney (1983) appropriately recommended that "a conservative approach to the maintenance of [ecosystem] services is through minimizing anthropogenic extinctions."

Energy Resources and Global Demand

Fuel energy use, which has accelerated tremendously worldwide in the last 30–40 years, is intimately related to land use. This is particularly true for the industrialized nations, where gross national products over the last century show strong correlations with increasing energy consumption [see, for example, the data for the United States in Cleveland et al. (1984)].

Hubbert (1973) documents some staggering worldwide data: "Cumulative production of crude oil up to 1970 amounted to 233×10^9 barrels. Of this, the first half required the 103-year period from 1857 to 1960 to produce, the second half only the 10-year period from 1960 to 1970." Further, Hubbert notes, "during the eight centuries [prior] to 1860, it is estimated that cumulative production [of coal] amounted to 7×10^9 metric tons. By 1970, cumulative production reached 140×10^9 metric tons. Hence the coal mined during the 110-year period from 1860 to 1970 was approximately 19 times that of the preceding eight centuries. The coal produced during the last 30-year period was approximately equal to that produced during all preceding history."

Most developing nations have sparse fuel energy reserves. Although the per capita energy use is much lower for the developing countries [for example, 7 and 17 gigajoules for India and China in contrast to 395 and 324 gigajoules for Canada and the United States (Chandler 1985)], bettering the standards of living and increasing food production are intimately related to energy availability. In jest, the point has appropriately been made several times that many developing countries may be able to achieve self-sufficiency in food production, but they will not have enough fuel energy to cook it. As a matter of fact, increasing food production itself depends largely on intensive energy inputs (Steinhart and Steinhart 1974, Pimentel 1980). Thus, while new, multiple, and adaptable strategies of energy supply and use must be implemented in the developing countries (see for example the discussions in Goldemberg 1983, Khoshoo 1986), conventional sources of energy must be used efficiently with proper safeguards for environmental rehabilitation. For example, steel production in India uses 41 gigajoules per ton whereas the world average is only 26 gigajoules per ton; Italy, Spain and Japan are leaders in this technology using only 17.6, 18.4, and 18.8 gigajoules per ton, respectively (Chandler 1985). "Sustainable development, of any type, is unlikely without energy efficiency as energy supplies decline and environmental impacts of fuel-use worsen" (Chandler 1986).

While search for new and/or more economical ways of harnessing atomic fusion, solar- and tidal power, and energy from biomass continues, the fossil fuels will continue to occupy a place of primacy well into the middle of next century. Of the latter, as the recent world events have shown, oil and gas have been mired in political linkages among countries. Although the recent "crash" in oil prices is most welcome in poor nations (and in import-dependent industrialized countries as well), the instability in pricing often has a debilitating effect on world economies (especially developing nations) as the period immediately after the 1973 energy crisis well illustrated.

I shall restrict my further comments here on the ecological consequences of surface mining for coal, the need for rehabilitation due to accelerated disturbance to land, and some of the strategies that may be used to rehabilitate ecosystem complexes. Worldwide, 3.7×10^9 billion metric tons of coal were produced in 1977. Trends between 1960 and 1977 "showed a gradual rise in production of coal in North America, a decline in production in western Europe and Japan, and substantial increases in southern Africa, Australia, and India (Griffith and Clarke 1979). Some estimates indicate that coal production will double in this decade, and triple by 2020. In India, the current production of 110 million metric tons of coal is likely to quadruple in the two next decades (Jha 1986). The drastic disturbances to land resources will be phenomenal unless effective mitigative measures are in place.

Disturbance and subsequent rehabilitation are intimately tied to the economic and social considerations of land use (Fig. 1). As has been pointed out (Wali 1975, Ashby 1977), each environmental disturbance presents its own unique trade-offs, and the development of energy resources is no exception.

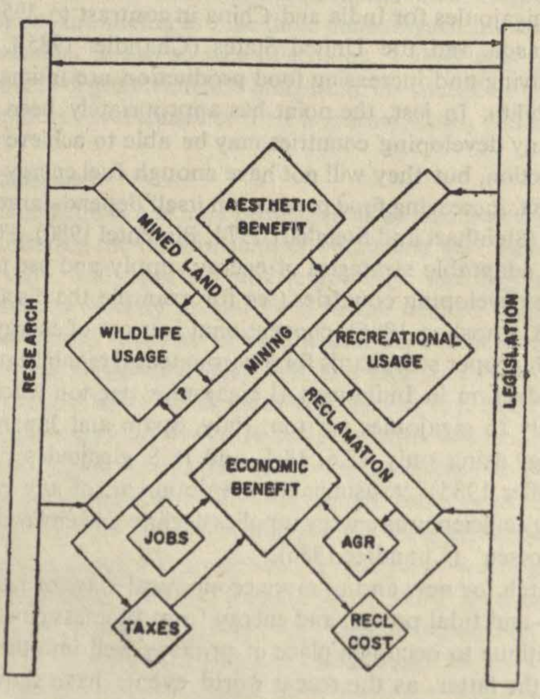


Fig. 1: The linkages of land rehabilitation in the matrix of social, economic, and environmental factors (from Wali 1975).

This necessitates the formulation and utilization of multiple land use strategies.

Structure-function of Disturbed Systems

A) MINED ECOSYSTEMS

Present day surface, strip, or opencast mining machinery has the capability of overturning 2 to 9 cubic metres of earth in one "scoopful" and bringing new parent materials from levels as deep as 60–70 metres. The parent materials that are overturned in the process of surface mining are generally termed "overburden" or "spoil" materials. These overburden materials are physically and structurally unstable and prone to subsidence, as well as chemically and hydrologically unsuitable for plant growth (Groenewold 1979, Groenewold and Bailey 1979).

Thus, the surface materials that natural processes have rendered suitable for plant growth over a time span of many millenia are deeply buried. It is imperative, before the initiation of any mining activity, to understand species diversity, the community structure, the microenvironmental features, the edaphic considerations, and their site-specific soil-plant-animal interrelationships of a given ecogeographic region. The availability of such information permits a reasonable forecasting of the potential as well as the expected productivity of mined areas (Wali and Freeman 1973, Fisser and Ries 1975). For example, differences in microclimate in mining areas within a distance of less than 48 km have been shown to be sufficiently distinct to be of ecological significance in revegetation (Wali and Sandoval 1975).

It is now generally agreed that mined areas must be treated in ways to enhance the successional process of a given ecogeographic area. Ecological succession, one of the central concepts in ecology, implies interlinked and concomitant changes in habitat properties, vegetation and associated biota over time. Succession begins with the invasion of plant disseminules and seeds from neighbouring areas on the harsh environments of surface materials newly excavated in the process of mining. Succession is considered *primary* when it is initiated on new land surfaces never before inhabited, as, for example, on bare rocks, and after volcanic activity. Abandoned mined land succession belongs in this category. *Secondary succession*, on the other hand, commences with the natural plant establishment on plowed fields that have been left fallow, or after logging by clear-cutting or heavy grazing. Thus, the colonizing sites (that have previously supported vegetation) start with leftover organic matter and nutrient accumulations.

Mined lands that, under mandated legislation in the United States, must be contoured, receive topsoil, fertilization and seeding follow a path similar to secondary succession (Wali and Freeman 1973, Wali 1980). Indeed, the rate of ecosystem change is faster on the latter sites than that reported from old field systems. There are, however, two major differences between mined systems that are carefully treated and old-field successions: (1) in abandoned fields or after logging, fires or grazing, the structural integrity of only a few inches of topsoil may be altered and the original soil profile sequencing is intact (for the most part) which is not the case for mined systems. Soil genesis in mined systems must proceed *ab initio*. (2) Parent materials excavated in the process of mining are not comparable to the plowed fields of agroecosystems and hence cannot be treated that way as some agricultural scientists have contended. It is questionable if standard fertilizers applied to the parent materials excavated during mining (which have laid buried for millions of years) will elicit the same response as when applied to naturally developed soil profiles. Lithological discontinuities, additionally, may be such that these, and the parent materials on which the native soils developed in the past, may be very different.

In the initial stages of ecological succession, the colonizers are few, and the habitat-pioneering species interrelations are simple. With the passage of time, the diversity of plant and animal populations increases, the species interrelations become much more complex, and nutrient cycles become much more intra-community dependent. Thus, with time the biotic community becomes relatively stable and resilient to short-term disturbances. It is perhaps these attributes of succession that convinced the lawmakers to include ecological succession as a major goal in the Surface Mining Control and Reclamation Act (U.S. Congress 1977). More of this legislation will be discussed later.

Thus, rehabilitation of mined systems should not be approached as a simple and simplistic extension of a few agricultural, silvicultural, and other applied science practices that been proven successful in vastly different situations. A fundamental understanding of ecosystem structure and function, including the processes of primary and secondary succession, must be well understood for any region (or nation) to achieve ecosystem rehabilitation quickly and reliably. Any short-term solutions sought without the cognizance of these factors, risk failure both from an ecological as well as an economic standpoint.

In the United States, mined systems east of the Mississippi River differ markedly from those that lie west of it. While in the eastern states, abundance of water greatly affects the neighbouring ecosystems, the paucity of water frustrates most rehabilitation efforts in the west. Generally, the eastern coal mining regions bear forest vegetation developed under a precipitation regime that exceeds evapotranspiration. The spoils excavated during mining contain appreciable quantities of iron pyrites which, under the influence of abundant water and physical and chemical weathering, release large quantities of both iron and aluminium. This enrichment results in a considerable lowering of the pH of water, and is collectively referred to as "acid mine drainage" (for a detailed discussion see Herricks and Cairns 1974, Caruccio 1979).

In the semiarid and arid west, the spoil materials are generally calcareous, alkaline, or sodic, or combinations of the three. The fine parent materials are unstable and subject to subsidence and piping (Groenewold 1979, Groenewold and Bailey 1979). Whereas water is perhaps the most important growth-limiting factor, the spoils exhibit a variety of nutritional deficiencies, and in some cases toxicities due to the excess of certain elements.

B) THE NORTHERN GREAT PLAINS OF THE U.S.: A CASE STUDY

1) *The vegetation-soil/spoil complex*

For nearly 15 years, our research has focussed on the northern Great Plains of the United States located west of the Mississippi River, in particular, the State of North Dakota. This state represents the confluence of four major vegetation types: (1) the westernmost extension of the eastern deciduous forest, (2) the easternmost extension of the Rocky Mountain elements, (3) the southernmost extension of the boreal biota, and (4) northern extension of the central Great Plains vegetation (Wali et al. 1982).

Here the climate is continental and predominantly semiarid, with 30 to 40 cm of yearly precipitation (75–80 per cent received during the 130-day growing season), warm and dry summers and very cold and dry winters, and prevailing northwesterly winds averaging 16 km per hour. Potential evapotranspiration far exceeds the incoming precipitation. The vegetation is mixed grass prairie dominated by grasses (*Andropogon scoparius*, *Agropyron* spp., *Bouteloua gracilis*), sedges (*Carex filifolia*, *C. heliophila*), forbs and low shrubs (Whitman and Wali 1975). Forests constitute less than one per cent of the total area of the state, are restricted to sheltered river valleys, and because of their importance, have been the subject of much ecological investigation (Burgess et al. 1973, Johnson et al. 1975, Wikum and Wali 1974, Killingbeck and Wali 1978, Wali et al. 1980). The three prevalent types of land use are native rangelands, pasture or haylands of introduced species, and croplands. The native rangelands are diverse and varied, depending upon precipitation, soil type, topographic position, and past management.

2) *The abandoned mined lands*

Prior to the 1970s, laws regulating mining in the states were either completely lacking, were based on engineering, rather than ecological, principles, or were not enforced. Surface-mined land areas were often a series of abandoned mined ridges and furrows. Our data, gathered over 12 years in North Dakota abandoned mined sites ranging in age from 1–50 years, revealed a slow progression of both species colonization and soil development (Wali and Freeman 1973, Wali and Pemble 1982). Species diversity in abandoned mined areas along a northsouth transect in western North Dakota showed that even after in 50 years, the species diversity (numeric prevalence) was only one-half that of neighbouring, unmined sites (Wali and Freeman 1973). However, Wali and Pemble (1982) found that relatively rapid changes in the habitats occurred in the first 17 years after mining. Sophisticated analyses of stand data (ordinations) revealed that site age was the most important factor in species diversity and composition.

When 53 site variables were included in the data matrix, stand-environmental complex ordinations revealed site age second to topographic variables in importance. The leaching of salts (particularly those of sodium and sulphate) was a relatively rapid process, whereas essential nutrient ions, including nitrogen and phosphorus showed an increase over time. Rates of nutrient accumulations were: organic carbon 13.1 g $m^{-2} yr^{-1}$; nitrogen 2.5 g $m^{-2} yr^{-1}$; phosphorus 0.01 g $m^{-2} yr^{-1}$; and potassium 0.49 g $m^{-2} yr^{-1}$. Carbon-nitrogen ratios, indicators of both soil fertility and productivity, showed the widest range for 1-year old sites (5–40) but values comparable to the unmined mixed grass prairie sites were found in approximately 50 years. Species distributional diagrams were devised to show their habitat preferences, a tool helpful in formulating species prescriptions for revegetation.

3) *The regulated mined lands*

Mined areas, that under the provision of new laws must be shaped such that they blend in with the surrounding topography, must receive topsoil (scraped from areas prior to onset of mining, and stockpiled), seeding with desirable species and fertilization show a much faster community change. In studies conducted on such areas in North Dakota, Iverson and Wali (1982a) found that four species of *Agropyron* (*A. smithii*, *A. caninum*, *A. elongatum*, *A. cristatum*) showed complete dominance in only four years from the initial spoil material manipulation and management. Perhaps as significant were rapid increases in the numeric component of species diversity: from 13 in year 1, to 19 in year 2, to 24 in year 4. The complete grass dominance in four years was aided most significantly by mechanisms of allelopathy (Wali and Iverson 1978, Iverson and Wali 1982a). Nutritional imbalances of phosphorus-manganese and phosphorus-zinc relations in *Kochia scoparia* seemed very important in the rise and fall of pioneering species (Iverson and Wali 1982), as were calcium uptake efficiencies (Safaya and Wali 1978).

In addition to seeding of desirable species, other seed sources appear to be particularly important. Ries et al. (1980) noted that the potential of prairie hay in supplying seeds not commercially available is immense and will help in "establishing plant communities readily available to undergo ecological succession." Their greenhouse studies were based on the germination of seeds from a hay source. During the initial stages of succession on mined areas in western North Dakota, however, Iverson and Wali (1982b) found that the dispersal of seeds in space (i.e., immigration from neighbouring areas onto manipulated sites) was much more important than dispersal in time (i.e., composition of the seed bank already present in the topsoil). But there is no question that in long-term community establishment, the topsoil is an important seed bank. Our studies placed great emphasis on a systems approach to rehabilitation and considered a myriad of interacting ecosystem variables in modelling these ecosystems (Figs. 2 and 3) (Wali 1975). Besides those presented above, we placed great emphasis on both the geochemistry of parent materials as well as the hydrogeochemistry of groundwaters, mobility characteristics of phosphorus (Harrell and Saeed 1979) which was established to be a deficient plant macronutrient in our earlier studies, in-depth investigations of spoil properties and needed amendments (Safaya et al. 1982), and the role of foliar fertilization to enhance the growth of plants (Malakondaiah et al. 1980). An intensive field and chemical study of a bighorn sheep (*Ovis canadensis californiana*) population provided insight into the forage preferences and nutrient dynamics of this important wildlife species (Fairaizi 1978). Aspects of species selection and consequent plant adaptability in stress environments deserve much attention in future revegetation studies. Safaya (1979), for example, discussed the new important line of thinking in "fitting" plants to problem soils (Fig. 3); Asay (1979) and Brown (1979) provided experimental confirmation of such ideas.

Rehabilitation Strategies

We recently pointed out that a preemptive national policy in all countries must clearly enunciate: (1) the level of resource need, (2) a realistic time table for resource development, (3) basic rules for resource management, (4) the standards for ecosystem rehabilitation, and (5) a prohibition of resource development in areas where damage to ecosystems will be irreversible (Wali and Burgess 1985). Recent reports from India clearly indicate that there are few ecosystems that have not been severely affected and yet there are few laws in place to regulate their mitigation (Centre for Science and Environment 1985). Thus, it should not be surprising that a recent decision by the Supreme Court of India, forbidding limestone quarrying in the absence of rehabilitation plans in the Mussoorie Hills, was hailed by many as a landmark ruling (Khoshoo 1986).

While the United States and India occupy two distinct geographic and climatic regions both have a diversity of ecosystems, from vast coastal strands to grasslands to mountain regions. Admittedly, India possesses three times the population of the United States with only one-third of the area. Nonetheless, the American experience should be indispensable, and much can be offered by the strides made both in the recognition of specific environmental problems, and in implementing effective ways to treat them (see Appendix I).

The crux of all rehabilitation strategies is the universal goal that can be

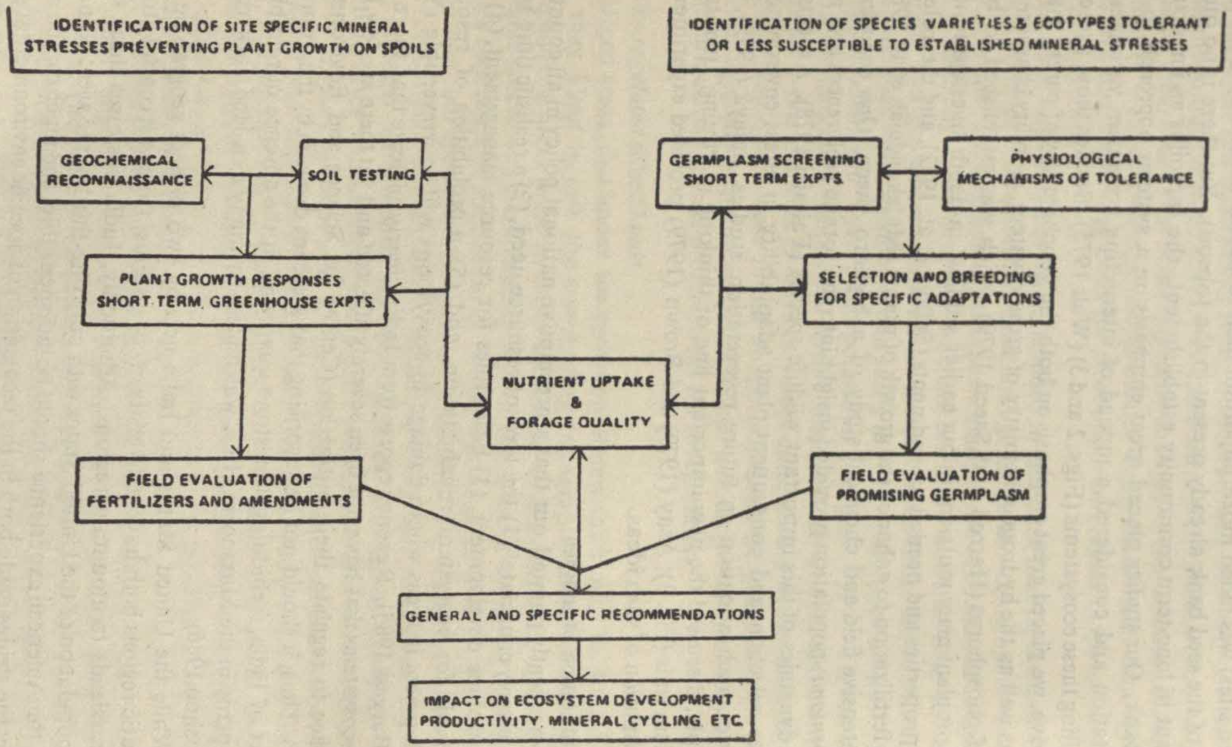

IDENTIFICATION OF SITE SPECIFIC MINERAL STRESSES PREVENTING PLANT GROWTH ON SPOILS
IDENTIFICATION OF SPECIES VARIETIES & ECOTYPES TOLERANT OR LESS SUSCEPTIBLE TO ESTABLISHED MINERAL STRESSES
GEOCHEMICAL RECONNAISSANCE
SOIL TESTING
GERMPLASM SCREENING SHORT TERM EXPTS
PHYSIOLOGICAL MECHANISMS OF TOLERANCE
PLANT GROWTH RESPONSES SHORT TERM, GREENHOUSE EXPTS.
SELECTION AND BREEDING FOR SPECIFIC ADAPTATIONS
NUTRIENT UPTAKE & FORAGE QUALITY
FIELD EVALUATION OF FERTILIZERS AND AMENDMENTS
FIELD EVALUATION OF PROMISING GERMPLASM
GENERAL AND SPECIFIC RECOMMENDATIONS
IMPACT ON ECOSYSTEM DEVELOPMENT PRODUCTIVITY, MINERAL CYCLING ETC.

Fig. 3. Model for delineating mineral stresses in mine spoils and screening plants for adaptability (from Safaya 1979).

summarized: To create multiple land use strategies that ensure long-term ecosystem stability and biological productivity. Let me illustrate with examples from events that took place in the United States in the last 15 years. During the early 1970's, in the wake of a strong environmental movement in the U.S., great concern was expressed for land rehabilitation. As a result, by 1976 38 states had passed new laws (or updated the old) (Imes and Wali 1977, 1978). These laws were to ensure that mined lands would be treated in ways that would accelerate the process of revegetation, which in turn would ensure habitat stability, decrease soil erosion, and effectively prepare the mined areas for quick recovery and useful biological productivity. The issues related to land rehabilitation have been judged to be very significant tempting us to propose a new branch of ecology, *mining ecology* (Wali and Kollman 1978), and to warrant two reports from the U.S. National Academy of Sciences specifically devoted to these issues (see Appendix II).

Never before in history has technology provided such enormous capability for moving large masses of earth and earned man the title of "the mighty geological agent". While such actions may be necessitated by resource demand, they also afford great opportunities. The multiple landuse concept, based on documented ecological characteristics of an area, was the central thesis advocated by a number of scientists in the United States and is evidenced by early state legislation: the coal mine operator's "plan shall designate which parts of the affected [mined] land shall be reclaimed for forest, pasture, crop, horticultural, homesite, recreational, industrial, or other uses including food, shelter, and ground cover for wildlife, and shall show the same by appropriate designation on the reclamation map" (North Dakota Century Code 1973).

At the federal level, legislation was proposed twice and vetoed by two U.S. Presidents, but the Surface Mining Control and Reclamation Act finally passed in 1977. Although many felt that the Act was a burgeoning jungle of statutes, it constitutes, in my view, landmark legislation which is both comprehensive as well as complex (Imes and Wali 1977, 1978). It took six years to reexamine many of the provisions of this Act, refine them, and issue the final rules (United States Department of the Interior 1983).

The intent of the federal legislation, and the responsibilities of different sectors of society, were aptly summed thus: "There should be strong emphasis placed on the performance of remedial measures in the field, with severe sanctions for failure to perform. In other words, actions taken by operators to abate a violation, and to correct an adverse environmental harm to land or water resources, do more for attaining successful reclamation than imposition of a multitude of civil penalties. In many surface coal mines, the cost associated with effective remedial measures greatly exceeds the maximum civil penalty that would be imposed" (Dwyer 1979).

Given the peculiarities of each ecogeographic region, no single model will apply universally. But a strong case exists for both the emulation and incorporation of ecological principles as well as for international cooperation (Curry-Lindahl 1978, Wali 1984), for land rehabilitation presents important social, economic and scientific challenges. Land Rehabilitation also affords unprecedented opportunities for basic scientific research on applied societal problems, indeed immense possibilities of enriching many concepts and databases of the basic and social sciences. Its relevance to sustainable development vis-a-vis land use in the developing countries should be unquestioned.

REFERENCES

Asay, K.H. Breeding grasses for revegetation of surface mine spoils in western U.S. In: M.K. Wali (ed.), *Ecology and Coal Resource Development*, volume 2. Pergamon Press, New York, pp. 1007-1011, 1979.

Ashby, E. *Reconciling Man with the Environment.* Stanford University Press, Palo Alto, CA, 1977.

Bhattacharya, S. Land, soil, rainfall, irrigation—some aspects of the backdrop of agrarian life in the *Arthasastra* of Kautilya. *Indian Economics Society Historical Review* 15: 211–219, 1978.

Brown, J.C. Plant energy as related to crop and land management. In: M.K. Wali (ed.), op. cit., pp. 994–1006.

Burgess, R.L., W.C. Johnson and W.R. Keammerer. Vegetation of the Missouri River floodplain in North Dakota. North Dakota Water Resources Research Institute, WI-221–018–73, Fargo, North Dakota, p. 162, 1973.

Caruccio, F.T. The nature of acid mine drainage reactions and their relation to overburden analysis. In: M.K. Wali (ed.), op. cit, pp. 775–781.

Centre for Science and Environment. The state of India's environment, 1984–85: The second citizen's report. Centre of Science and Environment, New Delhi, India, 1985.

Chandler, W.U. Increasing energy efficiency. In: L.R. Brown (ed.), *State of the World 1985.* W.W. Norton & Company, New York, pp. 147–171, 1985.

Chandler, W.U. The changing role of the market in national economies. Worldwatch Paper 72, Washington, D.C., 1986.

Cleveland, C.J., R. Costanza, C.A.S. Hall and R. Kaufmann. Energy and the U.S. economy: a biophysical perspective. *Science* 225: 890–897, 1984.

Curry-Lindahl, K. The significance of ecological principles for society. In: J.S. Singh and B. Gopal (eds.), *Glimpses of Ecology*, International Science Publishers, Jaipur, India, pp. 587–592, 1978.

Dwyer, J.W. Enforcement of P.L. 95–87 (The Surface Mining Control and Reclamation Act of 1977): Who does what? And when? And where? In: M.K. Wali (ed.), *Ecology and Coal Resource Development*, volume 1, op. cit., pp. 215–225.

Ehrlich, P.R. and H.A. Mooney. Extinction, substitution, and ecosystem services. *Bioscience* 33: 248–254, 1983.

Fairaizl, S.D. Bighorn sheep in North Dakota: Population estimates, food habits, and their biogeochemistry. M.S. Thesis, The University of North Dakota, Grand Forks, ND, USA, 1978.

Fisser, H.G. and R.E. Ries. Pre-disturbance ecological studies improve and define potential for surface mine reclamation. In: Third symposium on surface mining and reclamation, volume 1. National Coal Association/Bituminous Coal Research Coal Conference & Expo II, Louisville, KY, pp. 128–134, 1975.

Goldemberg, J. Energy problems in Latin America. *Science* 223: 1357–1362, 1984.

Griffith, E.D. and A.W. Clarke. World coal production. *Scientific American* 240: 38–47, 1979.

Groenewold, G.H. Hydrologic and hydrogeochemical characteristics of selected strip mine spoils in western North Dakota. In: M.K. Wali (ed.), op. cit., volume 2, pp. 769–774.

Groenewold, G.H. and M.J. Bailey. Instability of contoured strip mine spoils—western North Dakota. In: Ibid., pp. 685–692.

Harrell, J.W. and M. Saeed. Phosphorus diffusion in coal mine spoils. In: Ibid., pp. 798–806.

Herricks, E.E. and J. Cairns, Jr. Rehabilitation of streams receiving acid mine drainage. Water Resources Research Center Bulletin 66, Virginia Polytechnic University and State University, Blacksburg, VA. p. 284, 1974.

Hubbert, M.K. Survey of world energy resources. *The Canadian Journal of Mining and Metallurgical Bulletin* 66: 37–54, 1973.

Imes, A.C. and M.K. Wali. An ecological-legal assessment of mined land reclamation laws. *North Dakota Law Review* 53: 359–399, 1977.

Imes, A.C. and M.K. Wali. Governmental regulation of reclamation in the western United States. *Reclamation Review* 1: 75–88, 1978.

Iverson, L.R. and M.K. Wali. The role of *Kochia scoparia* and other pioneers in the revegetation process of surface mined lands. *Reclamation & Revegetation Research* 1: 123–160, 1982a.

Iverson, L.R. and M.K. Wali. Buried, viable seeds and their relation to revegetation after surface mining. *Journal of Range Management* 35: 648–652, 1982 b.

Jha, C.S. Technologies of exploitation and management of coal resources in India. Paper given at the 1986 Indian Science Congress Association, New Delhi [Mimeographed p. 18 +1 illus.], 1986.

Johnson, W.C., R.L. Burgess and W.R. Keammerer. Forest understory vegetation and environment on the Missouri River floodplain in North Dakota. *Ecological Monographs* 46: 59–84, 1976.

Khoshoo, T.N. Environmental priorities in India and sustainable development. Presidential Address to the 1986 India Science Congress Association, New Delhi, India. p. 224, 1986.

Killingbeck, K.T. and M.K. Wali. Analysis of a North Dakota gallery forest: nutrient, trace element, and productivity relations. *Oikos* 30: 29–60, 1978.

Malakondaiah, N., N. M. Safaya and M.K. Wali. Responses of alfalfa and barley to spoil and foliar application of N and P on a coal mine spoil. *Plant and Soil* 59: 441–453, 1980.

North Dakota Century Code. Chapter 38–14: 210–217, Bismarck, ND, USA, 1973.

Pimentel, D., editor. Handbook of energy utilization in agriculture. CRC Press, Boca Raton, FL, USA, 1980.

Prasad, E.A.V. Ground water in Varahamihira's *Brhat Samhita*. Sri Venkateswara University, Tirupati, A.P., India, 1980.

Ramakrishnan, P.S. Observations on the biological aspects of productivity of ecosystems. In: J.S. Singh and B. Gopal (eds.), *Glimpses of Ecology*. International Science Publishers, Jaipur, India, pp. 193–199, 1978.

Ries, R.E., L. Hofmann and W.C. Whitman. Potential control and value of seeds in prairie hay for revegetation. *Reclamation Review*. 3: 149–160, 1980.

Safaya, N.M. Delineation of mineral stresses in mine spoils and screening plants for adaptability. In: M.K. Wali (ed.), *Ecology and Coal Resource Development*, volume 2. Pergamon Press, New York, NY, pp. 830–849, 1979.

Safaya, N.M. and M.K. Wali. Growth and nutrient relations of thickspike wheatgrass and yellow sweetclover on a sodic mine spoil as affected by amendments and nutrient application. *Soil Science Society of America Journal* 43: 747–753, 1979.

Safaya, N.M., R.H. Bares, N. Malakondaiah and S.A. Nicholson. Ecological studies on the revegetation process of surface coal mining in North Dakota: 2. Physical and chemical properties of overburden and topsoils as affected by time and amendments. Minerals Environmental Technology, Bureau of Mines—United States Department of the Interior, Washington, DC, USA, 1982.

Singh, J.S. and M.K. Wali. The problem of soil erosion in some parts of Kashmir Himalayas. *Proceedings of the National Academy of Sciences*, India 32 (B): 118–124, 1962.

Singh, J.S. and M.K. Wali. Ecological problems in the western Himalayas. *Proceedings of the National Academy of Sciences*, India 33 (B): 55–57, 1963.

Steinhart, J.S. and C.E. Steinhart. Energy use in the U.S. food system. *Science*. 184: 307–316, 1974.

Tiagi, B. and B. Gopal, editors. Teaching of ecology and environmental sciences in India. International Science Publishers, Jaipur, India, 1978.

United States Congress. The Surface Mining Control and Reclamation Act, Public Law 95–87. Government Printing Office, Washington, DC, USA, 1977.

United States Department of the Interior, Office of Surface Mining. Revegetation of regraded areas and other lands disturbed by surface mining: Final rule. *Federal Register* 48 (171): 40140–40162, 1983.

Wali, M.K. The problem of land reclamation viewed in a systems context. In: M.K. Wali (ed.), *Practices and Problems of Land Reclamation in Western North America*. The University of North Dakota Press, Grand Forks, ND, pp. 1–17, 1975.

Wali, M.K. Succession on mined lands. Paper 23. In: *Adequate Reclamation of Surface Mined Lands*? A Symposium. Soil Conservation Society of America, Ankeny, Iowa, pp. 1–46, 1980.

Wali, M.K. International cooperation in ecological research. *INTECOL Bulletin* 10: 1–7, 1984.

Wali, M.K. and R.L. Burgess. The interface of ecology and law: Science, the legal obligation, and public policy. *Syracuse Journal of International Law and Commerce* 12: 221–253, 1985.

Wali, M.K. and P.G. Freeman. Ecology of some surface mined areas in North Dakota. In: M.K. Wali (ed.), *Some Environmental Aspects of Strip Mining in North Dakota*. North Dakota Geological Survey, Education Series 5, Grand Forks, ND, pp. 27–45, 1973.

Wali, M.K. and L.R. Iverson. Revegetation of coal mine spoils and autoallelopathy in *Kochia scoparia*. American Association for the Advancement of Science 78–2: 121–122, 1978.

Wali, M.K. and A.L. Kollman. Ecology and mining or mining ecology? In: J.L. Thames (ed.), *Disturbed Land Reclamation and Use in the Southwest*. The University of Arizona Press, Tucson, AZ, pp. 108–115, 1977.

Wali, M.K. and R.H. Pemble. Ecological studies on the revegetation process of surface coal mined areas. 3. Soil and vegetation development on abandoned mined lands. Mineral Research Contract Report, United States Department of the Interior-Bureau of Mines, Washington, D.C. 96 p., 1982.

Wali, M.K. and F.M. Sandoval. Regional site factors and revegetation studies in western North Dakota. In: M.K. Wali (ed.), *Practices and Problems of Land Reclamation in Western North America*. The University of North Dakota Press, Grand Forks, ND, pp. 133–153, 1975.

Wali, M.K., R.H. Bares and R.L. Burgess. Major woodland and shrub community types in North Dakota: A synthesis. *Proceedings of the North Dakota Academy of Sciences* 36: 34, 1982.

Wali, M.K., K.T. Killingbeck, R.H. Bares and L.E. Shubert. Vegetation-environment relationships of woodland and shrub communities, and soil algae in western North Dakota. North Dakota Regional Environmental Assessment Program (No. 79–16), Bismarck, ND. p. 1–159, 1980.

Whitman, W.C. and M.K. Wali. Grasslands of North Dakota. In: M.K. Wali (ed.), *Prairie: A multiple view*. The University of North Dakota Press, Grand Forks, ND, pp. 33–53, 1975.

Whitehead, A.N. The function of reason. Princeton University Press, Princeton, NJ, 1929.

Wikum, D.A. and M.K. Wali. Analysis of a North Dakota gallery forest: vegetation in relation to topographic and soil gradients. *Ecological Monographs* 44: 441–464, 1974.

APPENDIX I: Major Environmental Legislation in the United States since 1950*

Year	Public Law	General Title
1950	81-681	Fish Restoration Act
1953	82–212	Outer Continental Shelf Lands Act
1954	83–566	Watershed & Flood Protection Act
1956	84–1024	Fish and Wildlife Act of 1956
1960	86–705	Mineral Leasing Act
1964	88–577	Wilderness Act
	88–578	Land & Water Conservation Act Fund of 1965
1965	89–72	Federal Water Project Recreation Act
	89–80	Water Resources Planning Act
	89–272	Solid Waste Disposal Act
1966	89–665	National Historic Preservation Act
	89–669	National Wildlife Refuge System Administration Act of 1966
	89–702	Fur Seal Act of 1966
1968	90–399	Animal Drug Amendments of 1968
	90–454	Estuarine Areas Act
	90–542	Wild and Scenic Rivers Act
1969	91–190	National Environmental Policy Act of 1969
1970	91–224	Water & Environmental Quality Act of 1970
	91–512	Resource Recovery Act of 1970
	91–596	Occupational Safety & Health Act of 1970
	91–604	Clean Air Act Amendments of 1970
1972	92–340	Port and Waterways Safety Act
	92–464	Coastal Zone Management Act
	92–500	Federal Water Pollution Control Act Amendments of 1972
	92–516	Federal Insecticide, Fungicide, and Rodenticide Act
	92–522	Marine Mammal Protection Act
	92–532	Marine Protection, Research & Sanctuaries Act of 1972

	92–535	Bald Eagle Protection Act
	92–574	Noise Control Act of 1972
	92–583	Coastal Zone Management Act of 1972
1973	93–205	Endangered Species Act of 1973
1974	93–153	Trans-Alaska Pipeline Authorization Act
	93–248	Intervention on the High Seas Act
	93–254	Marine Protection, Research, and Sanctuaries Act Amendments of 1974
	93–319	Energy Supply and Environmental Coordination Act of 1974
	93–378	Forest & Range Land Renewable Resources Planning Act of 1974
	93–523	Safe Drinking Water Act
	93–627	Deep Water Port Act of 1974
	93–633	Transportation Safety Act of 1974
1976	94–370	Coastal Zone Management Act Amendments of 1976
	94–377	Federal Coal Leasing Amendments Act of 1976
	94–469	Toxic Substances Control Act
	94–477	Natural Gas Pipeline Safety Amendments of 1976
	94–490	National Weather Modification Act of 1976
	94–532	Whale Conservation & Protection Study Act
	94–579	Federal Land Policy and Management Act
	94–580	Resource Conservation & Recovery Act of 1976
	94–588	National Forest Management Act of 1976
1977	95–6	Fishery Conservation Zone Transition Act
	95–87	Surface Mining Control & Reclamation Act of 1977
	95–95	Clean Air Act Amendments of 1977
	95–155	Environmental Research, Development & Demonstration Authorization Act of 1978
	95–190	Safe Drinking Water Amendments of 1977
	95–192	Soil & Water Resources Conservation Act of 1977
	95–217	Clean Water Act Amendments of 1977
1978	95–273	National Ocean Pollution Planning Act of 1978
	95–307	Forest and Rangeland Renewable Resources Research Act
	95–372	Outer Continental Shelf Lands Act Amendments of 1978
	95–396	Federal Pesticide Act of 1978
	95–474	Port and Tanker Safety Act of 1978
	95–514	Public Range Lands Improvement Act
	95–541	Antarctic Conservation Act of 1978
	95–604	Uranium Mill Tailings Radiation Control Act of 1978
	95–632	Endangered Species Act Amendments of 1978
1979	96–95	Archeological Resources Protection Act of 1979

	96–118	Anadromous Fish Conservation Act
	96–129	Pipeline Safety Act of 1979
1980	96–193	Aviation Safety and Noise Abatement Act of 1979
	96–199	National Parks and Recreation Act Amendments of 1980
	96–223	Crude Oil Windfall Profit Tax of 1980
	96–229	Environmental Research, Development, and Demonstration Act of 1980
	96–255	National Ocean Pollution Planning Act of 1980
	96–270	Asbestos School Hazard Detection & Control Act of 1980
	96–283	Deep Seabed Hard Mineral Resources Act
	96–289	National Sea Grant College Program Act Amendments of 1980
	96–294	Energy Security Act
	96–310	Ocean Thermal Energy Conversion Research, Development and Demonstration Act
	96–320	Ocean Thermal Energy Conversion Act of 1980
	96–332	Marine Protection, Research & Sanctuaries Act Amendments of 1980
	96–336	Colorado River Basin Salinity Control Amendments of 1980
	96–345	Wind Energy Systems Act of 1980
	96–366	Fish & Wildlife Conservation Act of 1980
	96–368	West Valley Demonstration Project Act
	96–463	Used Oil Recycling Act
	96–464	Coastal Zone Management Improvement Act of 1980
	96–478	Act to Prevent Pollution from Ships
	96–482	Solid Waste Disposal Act Amendments of 1980
	96–487	Alaska National Interest Lands Conservation Act
	96–501	Pacific Northwest Electric Power Planning and Conservation Act
	96–502	Safe Drinking Water Act Amendments of 1980
	96–510	Comprehensive Environmental Response, Compensation and Liability Act of 1980
	96–515	National Historic Preservation Act Amendments of 1980
	96–567	Nuclear Safety Research, Development, and Demonstration Act of 1980
	96–573	Low–Level Radioactive Waste Policy Act
1981	97–23	Steel Industry Compliance Extension Act of 1981
	97–78	Combined Hydrocarbon Leasing Act of 1981–79
	97–79	Lacey Act Amendments of 1981
	97–88	Energy and Water Development Appropriation Act of 1982

	97–109	Marine Protection, Research, and Sanctuaries Act Amendments of 1981
	97–129	Toxic Substances Control Act Amendments of 1981
1982	97–293	Reclamation Reform Act of 1982
	97–304	Endangered Species Act Amendments of 1982
	97–348	Coastal Barrier Resources Act
1983	97–425	Nuclear Waste Policy Act of 1982
	97–440	Federal Water Pollution Control Act Amendment of 1983
	98–164	International Environmental Protection Act of 1983
1985	99–24	Biomass Energy and Alcohol Fuels Act Amendments of 1985

---

*Adapted from Wali and Burgess (1985). A few general comments on this table are in order:

1) A quick perusal shows that the body of environmental legislation in the United States is impressive, and most of it is working. Indeed, environmental law has emerged as a very important branch of jurisprudence in last 15 years in the U.S.

2) Of specific relevance to rehabilitation/reclamation is the Public Law 95–87, Surface Mining Control and Reclamation Act of 1977 and the Final Rulemaking (1983). In formulating new legislation, a careful reading of this Act is highly recommended.

3) While specific environmental issues are clear from the titles of the legislation in many cases, it may be cryptic in others and hence not readily apparent. For example, the Lacey Act Amendments of 1981 consolidate two existing wildlife laws, the Lacey Act of 1900 and the Black Bass Act of 1926; the new Act imposes maximum civil penalty for transporting alive or dead, animal and plant species, that are endangered and protected by law. Similarly, the Steel Industry Compliance Extension Act of 1981 extended to 1985 the current 1982 deadline for reducing air emissions, and the International Environmental Protection Act of 1983 are amendments to the Foreign Assistance Act of 1961 providing legal basis (and linking foreign aid) for the conservation of biological diversity in developing countries. These legislative mandates are further supplemented by other acts of the United States Congress, Presidential Executive Orders, and rules and regulations adopted by each of the 50 states. Of great practical significance as well, are the many ordinances that are passed at the county, city, and municipality levels; it is here that the implementation actually takes place.

4) The environmental law community reviews the performance of the United States Congress almost regularly [see for example, Kenneth L. Rosenbaum, Congress in 1983: Much oversight, little legislation, Environmental

Law Reporter 14: 10005–10010 (1984); James L. Conner II, Congress in 1984: A mixed bag, Environmental Law Reporter 14:10449–10457 (1984)]. The refinement of environmental legislation is a continuous process. Thus, the items for "productive agenda for environmental law reform" proposed by Phillip D. Reed [Reforming environmental law, Environmental Law Reporter 15:10062-10064 (1985)], reflect the maturation of enforcement process. These are: (1) *expansionist reforms* that would extend the law to problems now fully or partially outside its reach, such as increasing concentrations of carbon dioxide in the atmosphere and its attendant problems, and comprehensive groundwater protection; (2) *rachetting–down reforms* that would tighten control requirements for persistent problems like non–attainment of air quality standards or unsafe disposal of toxic chemical wastes; (3) *discretion-restricting reforms* would narrow administrative agencies' ability to fashion implementation programs; (4) *goal–balancing reforms* would put environmental values ahead of competing public interests and give society an optimal level of all goods and services, among them environmental amenities; (5) *economic-decision making reforms* would leave the goals of environmental law intact but would use cost–effectiveness analysis to make implementation as efficient as possible; (6) *targetting reforms* would eliminate programs that do not focus on the real problems; (7) *statutory-simplification reforms* would eliminate unnecessary variation among similar programs; (8) *simplified-decision making reforms* would reduce the number of oversight agencies; and (9) *cooperative-decision making reforms* would reduce adversarial conflict by negotiation rather than litigation.

APPENDIX II. Some books and bibliographies dealing with drastically disturbed ecosystems.**

United States Department of the Interior. Surface mining and our environment. Washington, DC, USA, 1967.

Barr, J. *Derelict Britain*, Penguin Books, Marmondsworth, UK, 1969.

Brown, L. J. (ed.) *Landscape Reclamation*. Volumes 1 and 2 (1972). IPC Science and Technology Press, London, UK, 1971.

Hutnik, R.J. and G. Davis (eds.) *Ecology and Reclamation of Devastated Land*, Volumes 1 & 2. Gordon and Breach, New York, NY, USA, 1973.

Wali, M.K. (ed.), Some environmental aspects of strip mining in North Dakota. Education Series 5, North Dakota Geological Survey, Grand Forks, ND, USA, 1973.

Jones, M. T. (ed.) Minerals and the environment. Institution of Mining and Metallurgy, London, UK, 1974.

National Research Council. *Rehabilitation Potential of Western Coal Lands*. Ballinger Publishing Company, Cambridge, Massachusetts, USA, 1974.

Wallwork, K. L. *Derelict Land*. David and Charles Publishers, Newton Abbott, UK, 1974.

**This list is arranged chronologically; the starting year 1967 has been chosen arbitrarily. The list is not intended to be complete but is designed to provide information to beginning researchers on a wide range of topics in land rehabilitation that have been discussed and investigated.

Goodman, G. T. and S. A. Bray. Ecological aspects of the reclamation of derelict and disturbed land: an annotated bibliography. Geo Abstracts Limited, Norwich, UK, 1975.

Wali, M. K. (ed.) *Practices and Problems of Land Reclamation in Western North America.* The University of North Dakota Press, Grand Forks, ND, USA, 1975.

Chadwick, M. J. and G. T. Goodman (eds.) *The Ecology of Resource Degradation and Renewal.* John Wiley and Sons, New York, NY, USA, 1975.

Vories, K. C. (ed.) Reclamation of Western Mined Lands. Ecology Consultants Inc., Denver, CO, USA, 1976.

Cairns, J., K. L. Dickson and E. E. Herricks (eds.) *Recovery and Restoration of Damaged Ecosystems.* University of Virginia Press, Charlottesville, VA, USA, 1977.

Down, C. G. and J. Stocks. *Environmental Impact of Mining.* Applied Science Publishers, London, UK, 1977.

Holdgate, M. W. and M. J. Woodman (eds.) *The Breakdown and Restoration of Ecosystems.* Plenum Press, New York, NY, USA, 1978.

Ripley, E. A., R. E. Redmann and J. Maxwell. Environmental impact of mining in Canada. Centre for Resource Studies, Queen's University, Kingston, Ontario Canada, 1978.

Schaller, F. W. and P. Sutton (eds.) *Reclamation of Drastically Disturbed Lands.* American Society of Agronomy, Madison, WI, USA, 1978.

Thames, J. L. (ed.) Reclamation and Use of Disturbed Land in the Southwest. The University of Arizona Press, Tucson, AZ, USA, 1978.

Wright, R. A. (ed.) The Reclamation of Disturbed Arid Lands. University of New Mexico Press, Albuquerque, NM, USA, 1978.

Gleason, V. E., compiler. Bibliography on mined-land reclamation. EPA–600/7–79–102, United States Environmental Protection Agency, Industrial Environmental Research Laboratory, Cincinnati, OH, USA, 1979.

Rummery, R. A. and K. M. W. Hawes (eds.) Management of lands affected by mining. Division of Land Resources, Council of Scientific and Research Organization, Perth, Western Australia, 1979.

Wali, M. K. (ed.) *Ecology and Coal Resource Development,* Volumes 1 & 2. Pergamon Press, New York, NY, USA, 1979.

Bradshaw, A. D. and M. J. Chadwick. *The Restoration of Land.* Blackwell Scientific Publishers, Oxford. UK, 1980.

Cairns, J. (ed.) *The Recovery Process in Damaged Ecosystems.* Ann Arbor Science Publishers, Ann Arbor, MI, USA, 1980.

Schiechtl, H. *Bioengineering for Land Reclamation and Conservation.* The University of Alberta Press, Edmonton, Alberta, Canada, 1980.

National Research Council. *Surface Mining: Soil, Coal, and Society.* National Academy Press, Washington, D. C. USA, 1981.

Sendlein, L. V. A., H. Yazicigli, and C. L. Carlson (eds.) Surface mining and environmental monitoring and Reclamation handbook. Elsevier Science Publishers, Amsterdam, The Netherlands, 1983.

Mandel, R. D. and M. E. Hines. Reclamation planning for coalmined lands: A selective bibliography. CPL Bibliography No. 151, Council of Planning Librarians, Chicago, IL, 1985.

American Society for Surface Mining and Reclamation. Symposium on reclamation of lands disturbed by surface mining: A cornerstone for communication and understanding. Science Reviews Limited, Middlesex, UK, 1985.

Brooks, R. P., D. E. Samuel and J. B. Hill (eds.) *Wetlands and Water Management on Mined Lands.* The Pennsylvania State University, University Park, PA, USA, 1985.

Schloesser, L. L., G. S. Anderson, N. M. Safaya and D. J. Thompson (eds.) Proceedings of the national symposium and workshops on abandoned mine land reclamation. Science Reviews Limited, Middlesex, UK, 1985.

Reith, C. C. and L. D. Potter (eds.) Principles and methods of reclamation science, with case studies from the arid southwest. University of New Mexico Press, Albuquerque, NM, USA. 1986.

12

Current Research on Forest Biology in India and Its Implications for Social Forestry and Agroforestry Practices

Peter S. Ashton

Summary

This report, the consequence of a one month assignment made on behalf of the Ford Foundation, from September 18 to October 18, 1983, is deferentially submitted in the hope that it may provoke discussion among your readers. They will be mindful that it is the product of a brief visit by an observer of limited experience of Indian conditions. It may, nevertheless, contain some of those insights with which the tyro, uncluttered by weight of detail, can at times be endowed. The author's mandate was to review research in forest biology at Indian institutions. In particular, he was to identify shortcomings and gaps in current research and training in light of practical developments in social forestry and agroforestry.

Overall, he has regretfully concluded that existing institutional structures have in recent years impeded the growth of the more experimental approaches to forest biological research, especially in plantation forestry of fast growing exotics, and the practical implementation of the work emanating from institutions conducting this research. However, the greatest deficiencies in forest biological research and training remain in the area of social forestry. This report focuses on that issue. Its conclusions can be summarized as follows:

Research Training. The Forest Research Institute and Colleges, for all their excellence and extraordinary potential, have left India without a cadre of high calibre scientists in forestry research; nor do Indian institutions currently provide the training and background needed for faculty positions, either

in forestry departments at the State Agricultural Universities, or at FRI & C. Career opportunities are increasing at the State Agricultural Universities. It is recommended that graduate scholarships be offered in response to the specific needs of the SAU's and to augment their programs. Once anticipated reorganization of FRI & C has been achieved though, graduate training opportunities should be greatly increased for staff there.

Research training should be based on Indian problems, with research conducted in the field in India. Those problems currently mostly stem from increasing shortages of forest-derived fuel, fodder and food. Visits to overseas institutions for some coursework and initial research supervision, and later for thesis preparation, nevertheless remain appropriate. Opportunities should be provided to improve the quality of training offered by Indian institutions, by offering overseas research experience to instructions of outstanding promise.

The number of women forestry officers and trainees is currently quite inadequate for the needs of social forestry. A scholarship scheme to attract more women to forestry and field research is recommended. The training should be based on Indian institutions, though opportunities to visit institutions overseas would act to broaden the education.

Successful interdisciplinary teamwork, a basic requirement in social forestry, depends on effective leadership based on previous experience of interdisciplinary work. The Indian Institute of Management, Ahmedabad, might be able to provide such training. Another possibility will be the Indian Institute of Forest Management at Bhopal, when it initiates suitable programs. Otherwise, it is recommended that suitable opportunities should be sought overseas for outstanding candidates.

It would seem desirable to establish a consortium of leading overseas and Indian universities, in order to give maximum opportunity for training in interdisciplinary science, team work, and leadership. An *ad hoc* coordinating board should be charged with development of programs as well as identification of candidates and research training priorities.

Research Support. Two clearly defined projects are suggested which could be achieved through sponsorship of individual scientists; and a broader program which could be encouraged through a lead grant.

First, an experienced silviculturalist with a strong background in statistics should be sponsored to compile a procedural manual for experimental trials in social forestry crops. The manual should include the principles and methods of project formulation, experimental design, and methods of monitoring, analysis and presentation of results. The author should be assisted by a peer-review panel.

Second, the most formidable impediment to enhancement of both forest and grassland production is uncontrolled cattle browsing, which prevents implementation of rotation systems. The problem is mainly social and exceedingly intractable, but a step in the right direction would be taken if a prize were offered for a cheap method of excluding cattle and goats from forests and pastures under rotation. The present favoured methods, of barbed wire and of ditch and thorn hedge construction, are impractical for large scale enclosures such as are required in protection forests on catchments. The former is too expensive hence liable to pilferage, whereas the latter is impossible on skeletal soils.

International exploration and exchange of germplasm for social forestry. As can be readily seen in the Indian example, social forestry work depends on a matrix of traditionally cultivated plants, many of which are confined to restricted regions, augmented by a limited number of strains of introduced species. Worldwide, the germplasm available for social forestry be it for fuelwood, fodder or medicinal plants or for domestic or commercial crops, is extraordinarily diverse but there is no systematic scheme to introduce and test species and provenances on a local, let alone on an international scale. Within the coming decades a substantial fraction of this resource will become lost forever through extinction because of tropical deforestation and increasing concentration on a few widespread crops and cultivars. A lead organization is needed to promote interchange, worldwide, of germplasm of plants of potential value in social forestry including agroforestry. India has institutions, such as the National Botanical Research Institution, Lucknow, which are well adapted to handle exchange, introduction and testing of such material, at least on the national level. The research results of these institutions have not been incorporated, to date, in plantation design in agroforestry. Indeed, they have hardly been integrated even in research trials. This would appear to be a further manifestation of the unfortunate gap that exists between the work of the research organizations and rural development practice.

Within India, exploration and collection, and a trial program for a full range of ecotypes of promising species, should be encouraged. In addition, Indian tree breeders and geneticists should be encouraged to collect a wider range of provenances of exotic species in their programs.

There is one other, perhaps more controversial area which, after careful planning, should make a useful contribution to amelioration of forest conditions and more judicious land-use: *Promote a dialogue between adherents of western and traditional Indian perceptions of the relationship between people and their environment.* Difficult though it will be to achieve, a series of discussion groups, perhaps at selected ashrams, should be arranged between rural leaders, swamis and professional foresters and environmental scientists, in an attempt to define a common understanding and address the complex problems of resource management and conservation in unison. A small number of specialists with Asian experience, in social anthropology, forest biology and agricultural economy, from overseas might be invited to collaborate with

Indian workers in coordinating a series of discussions with a mandate to define practical solutions.

India has the oldest continuous policy in scientific forestry in the tropics. Developed on the German model, high standards of administrative training, *esprit de corps*, and empirical silvicultural research into the sustained yield management of natural forests have been maintained since 1864. Since the 1960's, increasing population pressures have led to almost ubiquitous illegal incursions into the national forest estate for firewood, and uncontrolled browsing and grazing has undermined established silvicultural systems, which usually are based on natural regeneration. Injudicious logging practices, sometimes with connivance of corrupt officials, have combined with inadequate local consultation to exacerbate feelings of suspicion among villagers about forest department professionals and guards. The recent phasing out of logging contracts, and creation of state-run forest development corporations which are independent of the forest departments, are two among many indications of growing government concern over shortages of fuel, timber and other forests products in the rural sector, and over the future of the natural forest estate. A series of policy reviews have been sponsored by government and non-government agencies (Bahuguna, 1979; Chowdhry, 1983a; Department of Environment, 1983; Government of India, 1983; Ramachandran, 1981).

This report is based on experience gained at a limited number of institutions visited in India, combined with a rather brief review of recent Indian publications on social forestry (see bibliography). India currently has many institutions, including a variety of federal and state government agencies, and state agricultural universities (SAUs) and non-government organizations (NGOs), which are involved in work that concerns social forestry. This report therefore represents but a partial and incomplete view. Its concerns have, however, been discussed with several Indian workers, and the advice of Drs. A.N. Chaturvedi, K. Chowdhry, T.N. Khoshoo, P.K. Khosla, H.N. Mathur and P.V. Sane concerning my recommendations is particularly appreciated. Dr. William R. Bentley, the Ford Foundation, and Ms. Martha E. Avery, the Society for Wastelands Development, provided invaluable commentaries.

This report has been immensely facilitated by a recent sub-sector review of forestry education, training, research and extension in India (World Bank/USAID/ODA). My conclusions agree substantially with those contained in it. Rather than duplicate part of the contents of that review, I have chosen to focus more specifically on areas of potential interest to the Ford Foundation. This present review should therefore be read in conjunction with its predecessor.

Social Forestry in India

I understand social forestry to include all forestry operations in which members of the rural community participate in growing a forest product for their own needs or for their direct profit. The distinction between social forestry and production forestry, in which a forest crop is grown with or without assistance of paid local labour, is essentially arbitrary. Forestry practices such as forest department sponsored taungyas straddle the distinction, but the term is a useful one because it encompasses all forestry ventures where the primary objective is the direct benefit of villagers living adjacent to the forest resource.

Forestry as a rule is not financially competitive with agriculture on arable land. A forest crop can be more profitable than an annual agricultural crop to the owner of arable land, but this is so only because of high timber values due to increased scarcity, or savings in labour costs. The profit to the community as a whole may therefore be less, even though the individual landowner is better off financially. This is the case, for example, with some eucalypt plantations that are grown on irrigated arable land in Gujarat.

Biological Issues

Forestry generally is therefore confined to land unsuitable for sustained arable use. In the arable alluvial plains social forestry, including agroforestry, has its place on bunds, roadsides and canal banks. On arid lands and low fertility red soils, potentials exist on overgrazed pastures. Particularly on saline Usar lands reafforestation, through reduction of soil surface evaporation during the dry season combined with humification and consequent reduction in surface alkalinity, may in time allow partial reconversion to arable use. Degraded lands, currently abandoned for sustained forestry or arable use are termed wastelands. Though they yield sparse grazing, and sometimes firewood, their productivity can be enhanced by good husbandry wherever soil remains. Most of the area available in India for social forestry, however, comprises the degraded forests and wastelands on skeletal and erodable residual soils. These constitute the majority of the estimated 77,500,000 ha of all wastelands in the country (Society for Promotion of Wastelands Development, 1981).

Soil amendments, other than modest fertilization at first planting for forest plantations, generally cannot be justified on financial grounds, but they may sometimes prove unavoidable as an initial remedial measure. In marked contrast to agriculture, forestry requires a subtle appreciation of the diverse ecological conditions which limit where and how it can be practiced. Rather than the refinement through breeding of a restricted number of crop strains, to which soils can be accommodated through various forms of amendment, the forester must retain a broad array of species and "provenances" and build up a detailed casebook of empirical knowledge upon which species selection can be based. In short, the agronomist adjusts the site to the crop, whereas the forester adjusts the crop to the site.

Although India experiences rainfall seasonality throughout, almost half the lowlands were once covered with evergreen, semi-evergreen or moist deciduous forests where conditions of growth and reproduction for many insect and fungal pests are favourable for most and frequently all the year (e.g. Champion and Seth, 1968). Trees are too long-lived for it to be practical to breed disease resistance in any but the most valuable species. Biological control methods therefore are necessary, among which genetically heterogeneous single species plantings [as favoured in semi-arid land agricultural crops such as millet (Willey et al., 1977)] or mixed species plantations are particularly advantageous. Native species such as teak and sal, and introduced species such as eucalypts and subabul have proven successful in monoculture in the more equable lowland climates of India. It should be no surprise that their foliage is either indigestable or, at least to some degree, toxic as fodder.

Multiple-species crops are generally difficult to harvest in a single operation because of differences in timing of ripening. This can be exploited to advantage in forestry, however, if herbaceous agricultural crops are interplanted with forestry crops and some profit is realized early from what otherwise is a long-term investment—often too long for poor farmers. I define agroforestry as any combination of planted crops which yields an agricultural or horticultural product and a forestry product from the same land. Agroforestry is one mode of social forestry. Plantation forestry combined with fodder collecting, forage or grazing comes within the term, but not grazing or herbaceous crops in combination with fruit tree orchards, an ancient form of permanent agriculture which is similar agronomically, but which has no historical connection with forestry. Similarly, certain shrubby crops, such as pigeon pea (*Cajanus cajan*) and drumstick (*Moringa oleifera*) which yield both vegetable fruit and firewood, historically have been recognized as agricultural crops. My definition is arbitrary, but convenient, because it distinguishes those forms of land use in which the traditional roles of agricultural and forestry agencies must be married if satisfactory results are to be achieved.

Bad land will never be as productive as good land. In the absence of feasible soil amendments, expectations must not be set too high: For example, the many production figures for forest crops based on experimental plantations on arable land which find their way into reviews and policy reports. Nevertheless, I have been struck with the considerable opportunities that remain for enhanced production on the marginal and waste lands throughout India, including lands under forest department control. Generally, sufficient technical knowledge already exists, in both forest production and soil and water conservation, to achieve substantial improvements through social forestry, including agroforestry. There is an enormous potential, though, for introduction of new species, particularly of oil seeds and of other products for which there are serious shortages in India. The principal problems are socio-economic, and include training in better management, better interdisciplinary team work and, in particular, better interaction between advisory agencies and potential beneficiaries in the rural community (Chowdhry, 1983a). Some NGO's are successfully developing educational programs to meet these needs (e.g. Xavier Institute of Social Service, Ranchi 1983).

Social forestry projects on residual soils often will occupy catchments, and therefore will influence the soil and hydrology of the arable lands downstream. This requires that planning be set at an appropriate scale, and that priorities be clearly set among the multiple benefits that are to be expected. As an example of current interest, it has been shown at Kanpur, U.P., that eucalypts yielded more than double the biomass per hectare of other species tested, with lower water consumption per unit of biomass produced; but that water consumption by the eucalyptus was still almost double that of other species (Anon., 1983b; Chaturvedi, 1983). Eucalyptus root deeply. The claim that Eucalyptus affect dry season groundwater levels requires careful study and cannot be lightly dismissed. Eucalyptus foliage is rich in phenolic compounds and consequently indigestible as fodder. But eucalyptus are the most productive crop for firewood, charcoal and industrial timber on deep freely draining soils in the seasonal and semi-arid tropics. It is essential therefore that all consumers of the products (including water) of a site be consulted before eucalypts are planted, and that product values and site effects are clearly understood by all concerned.

As a rule, productivity declines in catchments from lower to upper slopes, and the frequency of water stress increases. Consequently, deciduous species are favoured on upper slopes. Ridges that are high enough, and so oriented to induce atmospheric condensation along their upper slopes or summits during the period of the dry trades, may support evergreen forests in the fog zone. These sholas, as they are termed in peninsular India, "rake" condensed water from clouds and thus sustain perennial streams. This capacity is a function of the geometry and surface area to volume ratio of the forest stand, and varies greatly among species. Pines and Eucalyptus appear less effective in this respect than the native forests. I have seen no awareness of this important consideration in Indian forest practice.

Research Considerations

1) METHODS OF CULTURE

A social forestry crop, as any other, needs to be rigorously assessed through well-planned and executed experiments and monitoring. It was here that I saw the most deficiencies in current practise. These deficiencies are not, it appears, in India alone but occur even in international agencies dedicated to agroforestry (Raintree, 1983).

Definition of objective: Ideally, the objective of a cropping system should be to maximise the yield of useful product in relation to the cost of production. In a market economy, this can be expressed in terms of net profit or present net worth. The value of a forestry product often changes considerably because shifts in supply or demand occur during the period between stand establishment and harvesting, so that profit projections are quite uncertain. Biological estimates, such as dry weight, biomass or calorific value of the useful products are informative because they are absolute measures, but the monetary value per unit volume or weight of the various products varies so much that this must be taken into account and predicted.

In practice, the choice of crop must be negotiated with the consumer; that is the villagers and particularly the village women in the case of social forestry. The subsistence economy consumer will have a reasonably clear idea of what she requires from the forest, but will not take risks. Therefore, she will be reluctant to invest in new products or cultural methods and these must be introduced through the mediation of demonstration plots. Experimental plots thus serve a dual purpose.

Design of Experimental Plots: Plot design must allow statistical estimates of the reliability of results, and clear identification of environmental correlates through the establishment of controls. With the noteworthy exception of the Usar (saline) land reafforestation trials jointly established by the U.P. Forest Department and the National Botanical Research Institute under A.N. Chaturvedi's supervision, and cropping systems with pigeon pea at ICRISAT (Willey et al., 1977), I saw little indication that these basic principles are understood in social forestry experiments.

Methods of Analysis: Social forestry experiments have been conducted in India for many years. Unclear definition of objectives, inadequate sample design and methods analysis and, particularly, the lack of standard methods of expressing results has prevented the use of previous experiments for improvement of techniques through accumulated experience, an essential element of the scientific method. I saw evidence that this need is still not appreciated. Workers in different institutions continue to plan and execute experiments *de novo* and without coordination, whose results will at best only apply to the site at which the experiment has been conducted. I also saw experiments with social forestry crops in which cost/benefits had not been carefully considered. Too often, the underlying economic and methodological assumptions seem to be based on agricultural norms, without taking account of the maxim, expressed earlier in this report, concerning the fundamental difference between agricultural and forestry husbandry.

Monitoring: Social forestry must be designed to be sustainable. Designs implemented at the community level must be tested by continued monitoring of yields and of the ameliorative effect of the forest culture on environment, including hydrology and soil erosion. This requires that estimates of rates of environmental degradation be obtained from the site before initiation of the project. Similarly, population trends in the communities which depend on the forest culture require monitoring.

Such data, even where some measure of soil erosion continues, are essential if the returns on an investment in social forestry are to be assessed. The value, and in particular the durability, of the small scale irrigation projects at Sukhomajri and Nada in Haryana for instance, are accessible to assess for this same reason.

2) CROP HUSBANDRY AND CROP CHOICE

Traditionally, villagers have expected forests to provide a variety of goods and services, on a continuing basis, from a single stand. These may include construction and other timbers, cordage, firewood, fodder, and often grazing, fruit, oil seeds (e.g. Mahua, Sal), as well as a clean reliable water supply and cool ambient temperature. When intensity of use increases, whether unsystematically as a result of population increase, or by design through planned agroforestry, one or more of these uses come into inevitable conflict (Agarwal et al., 1982; Bahuguna, 1979; Bhatt, 1980; Chowdhry, 1983a; Gupta and Bahuguna, 1982; Gupta et al., 1981). Techniques for reducing such conflicts exist, but require solid community support to implement. This seldom has been achieved in recent times.

Timber: Regeneration, whether natural or planted, must be protected from fire, browsing and lopping during its early years. For most species a minimum of five years is required. Successful methods of exclusion, particularly of grazing animals, have eluded the forest departments and panchayats, though small schemes by private land owners and NGOs have been successful. Sukhomajri and Nada provide successful examples in this respect, as do several projects initiated by the Tata Rural Development Society and the eco-village forestry scheme sponsored by Himachal Pradesh Agricultural University with Planning Commission funding.

Firewood: In much of the current literature of 'the firewood crisis', there is a failure to recognize that rural households in India and much of the rest of Asia have relied principally on stubble, dried leaves and twigs for cooking fuel. Such fuel remains in plentiful supply to villagers in all but the arid parts of India. The demand for firewood and charcoal is mainly urban (Joshi et al., 1983). As urbanization has proceeded, prices have soared, providing an increasingly lucrative source of income to villagers. In spite of this, I was unable to verify tales of women having to walk 15 km in search of fuel for home use in Bihar or elsewhere outside the arid zones. There, the use of dung as fuel remains a widespread tradition, which deprives farmers of a principal source of mulch. The problem is certainly more severe in the semi-arid and arid regions, where fuelwood is in shortest supply. Distances to sources seldom exceeded 5 km in the less arid regions, but many village women walked considerably greater distances in order to market firewood to entrepreneurs or sell it themselves in town markets. It is reported that firewood is brought up to 700 km by train and truck to Delhi, where 40% of fuel needs are still met by fuel and charcoal.

Native forests do not have the capacity to yield firewood on the scale now required. Fast-growing firewood crops can become an important source of income to villagers. Species suitable for the variety of climates and sites available for social forestry are already identified (National Academy of Sciences, 1980), but many more productivity studies under Indian conditions are needed along the lines of Chaturvedi's experiments on Usar lands. State forest department initiatives, providing seedlings and advice and establishing buffer belts of firewood species around the margins of forest reserves, are becoming increasingly successful and will aid in changing the unpopular, authoritarian image which foresters present in the minds of villagers. The departments should guard, however, against overoptimistic forecasts of yields, and should undertake more frequent and careful monitoring.

Fodder is not exported from the villages in significant quantity. It is nevertheless an important source of animal food, particularly during the dry season. It poses a more difficult problem of management than firewood as cash incentives cannot be introduced until fodder enters the commercial market on a significant scale. Control of the methods and extent of fodder cutting in forests, whether legal or otherwise, has proven difficult in the absence of clearly established rights of ownership on state and panchayat lands. Plantation of fodder species would appear to be obligatory, but methods to induce voluntary participation may prove difficult for the same reason. Much more research is needed on the nutritional value of fodders, and on the productivity and appropriate lopping methods for different species (National Academy of Sciences 1977, 1979). Methods of evaluation require careful thought, and may best be expressed in terms of net profit obtained from the eventual product: milk, meat, or animal power.

Grazing is the most serious agent of land degradation in lowland India, and provides a poignant example of the social, rather than biological, problems that must be resolved if more productive land use is to be achieved. As grazing pressure increases, perennial grasses and forage crops increasingly fail to survive the dry season. Eventually, a low productivity sward results, dominated by annual grasses which generally germinate, grow and die during the monsoon and the cool dry season (Society for Promotion of Wastelands Development, 1981). It has been demonstrated that rotational exclusion of grazing animals through the monsoon can lead to reinvasion by perennial grasses and a dramatic increase in production. Highly productive grasses and nutritious leguminous forage can be introduced, which allows areas to be excluded altogether from grazing and clipped for dry season hay. There will be ameliorating effects also on adjacent non-grazing land. Ideally, stall feeding should be utilized. The investment probably can be justified in the case of milch cows as greatly increased milk flow can be anticipated, but not for draught animals alone. Customary grazing rights are difficult to renegotiate, however, and village cattle often belong to owners in a variety of castes, such that no single spokesman for change can be identified.

The effects of light shade on milk production in hot climates is well-established. I am unaware of experiments to introduce broad-crowned trees which cast light shade and yield valuable timber, such as the rain tree (*Samanea saman*), to grazing land.

Traditional forest goods and services. Villagers in India have habitually been granted customary rights to a variety of forest products which they may freely gather (Central Institute of Medicinal and Aromatic Plants, Lucknow 1981–82 Annual Report and Technical Information Brochure; Kapoor Mitra, 1979; Khosla, 1983; National Botanical Research Institute, 1981, 1979). Critical quantitative study of the importance of these commodities to the village economy, now being conducted under the Common Property DAP (PA 82–732), is crucial to forest policy planning. A major source of the hostility with which villagers view the forest departments is the destruction of these resources by logging contractors, and their selective reduction in regenerated forests. Recent legislation against hunting within forest reserves has added to the resentment. The problem is a further manifestation of the forester's traditional concentration on production forestry for urban, state or wider markets without sufficient consideration of community needs. Customary rights have been honoured, but no attempt has been made to conserve the resources to which villagers in a sense hold title. The villager thus views the forester with much the same disfavour that the forester views him—and with legitimate reason.

Homestead mixed orchards in Asia have their origin in South India, though they have been developed to their greatest sophistication in Indonesia (Williams et al., 1975). Particularly well developed in Kerala, such orchards generally are planted on rainfed, often erosion prone or skeletal soils close to homesteads. They yield a modest but steady supply of carbohydrate, fruit, timber, cordage, and medicinal plants throughout the year. An example of a homestead mixed orchard tree is the Jackfruit, *Artocarpus heterophyllus*, whose seeds are such an important source of carbohydrate and fat in Java that commercial orchards are profitable and competitive on arable land. The Jackfruit, an evergreen, grows well on the lower slopes of hill catchments, even in semi-arid regions.

Homestead mixed orchards are a form of agroforestry which merit greater development in the Deccan and other semi-arid regions. Oil-seeds, lac, and tussar-silk host trees and other 'minor forest products' of importance to the village economy can be restored, and cooking fuel for household needs simultaneously provided.

Species selection. Systematic selection of species and strains for social forestry projects is only just beginning (Khosla, 1983; Khoshoo, 1982). This should be given highest priority, for the full potential of social forestry is on this account not being realized. The advantages of selection of appropriate ecotypes, in terms of compatibility in mixed plantation, yield, time to production, convenient propagation, coppicing and growth characteristics, ameliorative effects on soil, water relations, and disease resistance have not been systematically investigated.

Available species and provenances from other regions of the world are very restricted in India. There remains an immense variety of traditional woody crops in other parts of the tropics that has never been tested in India. Current high rates of deforestation in the tropics are leading to extinction of little known species of potential economic value. Concurrently, traditional village species are being replaced by a restricted group of widely grown species or by herbaceous crops.

Plants deserving special priority for introduction and trial in India include oil seeds such as Borneo Illipe (*Shorea* section *Pachycarpa*) and the Brazilian Babassu palm (Orbignya); shelter, firewood and fodder trees for semiarid regions such as *Acacia sayel*; and a diversity of plants of pharmaceutical value.

In the National Botanical Research Institute at Lucknow, India possesses a world-class institution that could serve as a clearinghouse for exchange of such germplasm worldwide and a testing agency for the variety of ecological conditions occurring at home. It is at interspecific and higher scales of genetic variability that performance tests currently need to be concentrated. For most species, it is too early to invest in breeding programs for selection of elite strains of woody species for social forestry under the variety of conditions occurring in India. Exceptions include established woody species such as pigeon pea (Agarwala et al., 1981; Anon., 1980; ICRISAT, 1982), which can produce one to six tonnes dry-weight of wood per hectare; subabul (*Leucaena leucocephala*) (Agarwala et al., 1981; National Academy of Sciences 1975, 1979); and the eucalyptus (Anon., 1983b; Chaturvedi, 1983). In the latter two examples the genetic diversity occurring through their natural range is poorly represented in Indian plantings, and further collection of promising genotypes from the wild should be a priority.

Even with the present restricted range of species used in social forestry, availability of seed and seedlings often is unpredictable. There appears to be no technical reason why this is so.

3) SOCIO-ECONOMIC ISSUES

Socio-economic issues do not come within the scope of this report but they, rather than biological-technical issues, provide the most serious obstacles to successful implementation of social forestry today in India. Social forestry projects are prohibitively expensive if implemented primarily by forest department staff, and have less chance of protection than when they are the responsibility of villagers. There remains a fundamental difference of perception of forest resources between forestry personnel, who are trained in the western traditions of legal protection and sustained yield management for the needs of industry and the nation, and the poorer villager, whose priorities are to meet immediate family needs and whose traditional constraints on overexploitation, embedded in mythology and religion, are relaxing in the face of the blandishments of the money economy (Agarwal et al., 1982; Bahuguna, 1979; Bhatt, 1980; Chowdhry, 1983a).

It is tempting to see social forestry as a vehicle for achieving social change. This adds a further complication to an already complicated strategy and would therefore seem impractical. Successful social forestry will inevitably lead to social change, however, if only through unequal distribution of its benefits. These changes clearly need to be anticipated, monitored, and where possible reconciled.

Central to the success of social forestry is an appreciation of the centres of power within the village, for acceptance of new land-use policies must first be achieved at village level (Chowdhry, 1983a, b). Recognizing that the legal means to protect forest reserves and protected forests have failed, some SFDs have concentrated their efforts on those who are principally responsible for illegal inroads into these forests: the landless, and subsistence farmers on marginal lands. Non-arable state land has been transferred to the former for agroforestry plantations, and seedlings and advice provided to the latter. In some states, notably Gujarat, medium and large land-owners have readily taken to forestry on arable land. This has not always benefitted the community as a whole as this form of land-use has been preferred over agriculture because it reduces labour costs.

There is continuing dialogue as to the merits of deaccession of parts of forest reserves and protected forests that have become wastelands. On the one hand, power is thereby transferred to the individuals who will benefit from careful husbandry of the reforested land. On the other, the government agency thereby foresakes any control it still has over the future use of the land. In this context, the concept of usufruct is well established in India and has advantages, at least with short rotation woody crops, over transfer of land title. The most favourable solutions seem to be when the forest department retains land ownership, but draws up contractual agreements for periods up to ten years for the growing of agricultural crops and fuelwood, on the condition that a timber crop is interplanted and the ensuing crop protected. In addition, long-term agreements for profit sharing, or partial ownership of the crop by villagers would seem desirable.

These notions appear to be unpopular among villagers used to the concept of customary rights, but should not be dismissed merely on that account. In many areas, establishment of social forestry projects on private and state non-forest land is already reducing the pressure on the forest estate, giving breathing space during which new agreements can and must be negotiated. Where this occurs, the reform of customary rights, and their redefinition as fixed-duration leases to products, must then be a priority.

Various NGOs, including TSRDS (Anon., 1983a) and SPWD, have initiated projects through establishment of village community associations. But India seems not to have a tradition of democratic village government such as that pertaining among the Balinese (Covarrubias, 1937). The 'tragedy of the commons', as manifested by the sorry state of panchayat lands throughout the country, should serve as warning that community associations will likely only remain effective if the NGO's maintain a permanent commitment to projects they have sponsored. This commitment is not generally anticipated by agencies. The pattern of land-use, agricultural and forestry techniques, and market forces will continue to change, also necessitating maintenance of effective channels of advice and assistance. The concept of 'resident village motivators', and the need for a single, coordinated extension service for agriculture and forestry, receive full discussion in the World Bank/USAID/ODA report, and are clearly of the greatest importance.

There is growing awareness, at last, of the role of women in social forestry. Women and children take principal responsibility for firewood and fodder collection, and for grazing, and thus are *de facto* the adjudicators over the fate of the forest estate. The Chipko movement (Bahuguna, 1979; Bhatt, 1980; Agarwal et al., 1982; Gupta and Bahuguna, 1982) has demonstrated the power which women, when organized, can wield in assuring the sustained yield management of forest resources. This movement has also highlighted the potentially conflicting interests that rural women and men have in the forest resource. Men, seeking employment and cash, will readily see the forest, upon which women rely for household needs, leased to a contractor. Foresters and forest scientists so far have paid too little attention to these issues, partially doubtless because so few of them are women (see e.g. Gupta et al., 1981; Government of India, 1982). Such grass-roots movements therefore find leadership among politicians who are unlikely to appreciate all aspects of forest management and conservation.

A visitor to the sacred groves of the Khasi hill tribes, now surrounded by worn-out jhum fields; or, as in my case, to the 50 ha virgin forest, set in paddy fields, which surrounds the Iringole Bhagvathi temple at Perumbavoor, Ernakulam, Kerala, cannot fail to note that religious constraints still hold fast where the rule of law has long since become ineffectual. Indian religious tradition often is remarkably consistent with contemporary environmental theory—a fact not missed by the leaders of the Chipko movement. Yet ecologists and foresters have maintained a cautious distance from the spokesmen for traditional values. In view of the considerable hold that traditional values undoubtedly still have, this attitude would seem particularly unfortunate. The issues are undoubted complex but, because they are close to the root causes of so many contemporary problem in rural India, they simply cannot be avoided.

Institutional Capabilities in Forest Biological Education and Research

This subject has been adequately covered in the World Bank/USAID/ODA review, so I will confine myself to a few comments.

I respectfully submit though that the quality, and in particular the capacity for innovation, of forestry research is currently compromised by the institutional structure of the Forest Research Institute and Colleges, Dehra Dun. Notably, the failure to establish a career structure for research and training staff of equal standing with that of IFS administrative officers has made it difficult to attract the best minds, and adversely influences morale.

The reservation of all senior positions at FRI & C for IFS forestry administrators, coupled with rigid adherence to service rules regarding transfers, though appropriate for administrative officers, has led to lack of continuity and lack of professionalism in forest research policy; and inability to accommodate new technologies and approaches to forest science in research programs or their implementation in forestry practice. Research programs are fragmented, perhaps particularly in forest biology, and conducted in isolation at a time when a team approach is mandatory. Once the leading institution in tropical forestry research, FRI & C continued its traditional emphasis on empirical silvicultural, systematic and pathological research into native forests, while institutions in other countries overtook it in advancing plantation research and now social forestry.

The FRI & C is failing to meet training needs, at all levels from IFS to rangers. Notably, the isolation of FRI & C from a university has prevented forest education from gaining inputs from other disciplines, notably modern experimental approaches in biology, but also economics and social sciences. FRI & C may be the only remaining forestry college in the world without university affiliation (Khosla, 1983).

Meanwhile, several forestry departments have been established as State Agricultural Universities, and some states, notably Kerala and Uttar Pradesh, have established forest research capabilities. The benefits to be gained from these provincial institutions are manifest. Significantly, whereas a paltry 3% of current IFS diploma course participants are women in this era of social forestry, many more women were noted to be taking forestry at Birsa Agricultural University. But there are also disadvantages with the forest education provided by SAUs. There is considerable variability in standards and sometimes low quality control. I noted, for example, an emphasis on research and interdisciplinary training, and a dynamic approach to instruction at Himachal Pradesh Agricultural University; but saw inadequate understanding of the scientific method and a somewhat rigid and unimaginative approach to curricular development at some others.

The great strength of the FRI & C diploma is its creation of a broad, all-India 'brotherhood of the elect.' There is much good in the relative impartiality and incorruptability of this senior cadre in IFS, and it owes this to the diploma course. Also, diploma students do much field work throughout India, with a conscious emphasis on 'toughening-up'. These indispensable elements currently are unavailable at state universities. It is clear that future Indian foresters must be provided a training which benefits from the respective advantages of each system. Until the Government of India has decided the future role of FRI & C in forestry education, there remains an urgent need for overseas training for forestry, including agroforestry, researchers. I believe that there are two principal, interrelated, reasons for this: Forest biological research approaches, particularly in FRI & C, appear too much to be set by staff themselves rather than defined by the needs of clients. In contrast, the forest department of Himachal Pradesh Agricultural University has an active advisory board on which foresters and representatives of government and industry sit. Effective research in social forestry requires an interdisciplinary approach. On the one hand, it demands teamwork between staff in the forestry department and at least one agricultural department. On another, it requires close interaction between the research teams, administrative officers and the rural community. And on yet another, it requires joint teamwork among forest scientists, soil scientists, economists, and social scientists. The training provided at FRI & C is ill-adapted to such needs.

The Indian Council of Agricultural Research is a funding agency which also conducts research through its own stations. It would appear to be the instrument most able to insure better focus and coordination in forestry research, particularly research into social forestry including agroforestry, and implementation of some means, such as peer review, to ensure quality control. An Indian Council of Forestry Research and Education quite appropriately was recommended by the World Bank/USAID/ODA team.

The Track Record of Outside Assistance

GOI and several bilateral and multilateral aid agencies have started or are negotiating a variety of state-level social forestry projects. SIDA has projects in Tamil Nadu and the Aravalli range, with further under negotiation in Orissa and Chotanagpur Plateau. They have a further, agroforestry project in West Bengal, and one in the Sunderbans in silvopisciculture (Werner, 1982).

Concentrating on socio-economic aspects, the focus is on the poorest members of the community and on women. SIDA is also aiming to improve soil conservation. It has projects in management training, too, and in survey methodology, information storage, and communication. The Tamil Nadu project, started in 1981, has revealed shortcomings in methodology. Demonstration of increased production through social forestry/agroforestry is obligatory for community acceptance. Most monitoring, which has been carried out in collaboration with several universities, is social and is fairly rudimentary. All forestry, including forest biological research, is the responsibility of the State Forest Department. No monitoring of production seems to be undertaken. All that is available is a rough measure of seedling survival. Only these somewhat modest successes have been achieved by the agency with the best record for thoroughness and consistency.

USAID has two projects in process: one in Madhya Pradesh an another in Maharashtra, which may involve a research subcontract to the Bharatiya Agro Industries Foundation. They are also promoting a plant biomass project. Results to date are too preliminary to evaluate.

The World Bank, after experience with a self-help woodlot project in Gujarat which failed, has concentrated on support for the planting programs of various SFDs. They conclude that SFDs have been oriented towards achieving annual planting targets, and that extension and follow-up has been poor. The Bank is now assisting in establishing a national social forestry unit, providing lines of credit, as part of the current national five-year plan.

Currently, state forest departments take the lion's share of responsibility for social forestry. Planting targets are often unrealistically high though. Besides, all other forestry projects also have to receive the approval of SFDs.

Under the circumstances, it is my conviction that NGO's, and in particular foreign agencies, should very seriously consider the full implications before they underwrite individual social forestry projects at present, for these implications include the following:

The methodologies, social, economic, and biological, need much more research before a reasonable chance of success can be assured for all but the most modest programs.

Long-term monitoring is obligatory if such a project is to be rigorously evaluated. Extension services should be introduced on a permanent basis.

Changes in the administrative structure and relationships of the Division of Forestry in relation to other divisions within the Indian Ministry of Agriculture are likely. The administrative problems currently associated with successful implementation of social forestry projects are great. It would be better to await the outcome of these administrative changes.

REFERENCES

Agarwal, A., R. Chopra and K. Sharma (eds.). The State of the Environment: A Citizen's Report. Centre for Science and Environment, New Delhi, 189 pp., 1982.

Agarwala, V.P., D.W. Seckler and K.G. Tejwani. Energy from Trees: The Second Green Revolution in India. Society for promotion of Wastelands Development. 48 pp. plus appendices, 1981.

Anon., Proceedings, international workshop on pigeon peas. ICRISAT, Patancheru, India (and references therein), 1980.

Anon., Birsa Agricultural University on the march. Commemoration brochure. 46 pp., 1982–83.

Anon., Tata Steel : the company that cares. Brochure. 12 pp., 1983a.

Anon., Editorial : Eucalyptus and Social Forestry. *Evergreen*, 10: 1–2, 1983b.

Bahuguna, S.L. The Himalayas: Towards a programme of reconstruction. *In:* Gupta, K.M. and D. Bandhu (eds.), *Man and Forest—A New Dimension in the Himalaya.* Today and Tomorrow Publishers, New Delhi, pp. 141–151, 1979.

Bhatt, C.P. Eco-system of the Central Himalayas and Chipko movement. Shishupal Singh Kunwar Dashuli Gram Swarajya Singh Gopeshwar, Chamoli, Uttar Pradesh, 40 pp., 1980.

Birsa Agricultural University, Ranchi (undated). Development Project of Faculty of Forestry, 28 pp.

Birsa Agricultural University, Ranchi, Faculty of Forestry (undated). Courses of study for two years diploma and three years degree in forestry, 85 pp.

Birsa Agricultural University, Faculty of Forestry, Annual report, Mimeo, 10 pp., 1981-82.

Birsa Agricultural University, Faculty of Forestry, Annual report, Mimeo, 16 pp., 1982-83.

Birsa Agricultural University, Progress report. Ford Foundation scheme, Mimeo, 18 pp., 1982-83.

Bogaert, M. van der. Approach to the preparation of basic literary materials with reference to tribal and regional languages. Paper presented at National Seminar on Adult Education for Linguistic Minorities and Tribal Population, Ranchi. 171 pp. + appendices, 1982.

Central Institute of Medicinal and Aromatic Plants, Lucknow. Annual report. 129 pp., 1981-82.

Central Institute of Medicinal and Aromatic Plants, Lucknow. Technical information. Brochure. 21 pp.

Champion, H.G. and S.K. Seth. A revised survey of the forest types of India, Delhi. 404 pp.,1968.

Chaturvedi, A.N. Eucalyptus for farming. *Uttar Pradesh Forest Bulletin 48.* 48 pp., 1983.

Chowdhry, K. Social forestry and the rural poor. *Discussion Paper No. 10*, Ford Foundation, New Delhi. 33 pp., 1983a.

Chowdhry, K. Schools as partners in social forestry. *Discussion Paper No. 11*, Ford Foundation, New Delhi. 8 pp., 1983b.

Covarrubias, M. The Island of Bali. Knopf. 405 pp., 1937.

Department of Environment. Recommendations regarding the revision of the National Forest Policy. New Delhi. 19 pp., 1983.

Forest Research Institute and Colleges, Dedra Dun. Annual report, 25 pp. + appendix, 1981-82.

Forest Research Institute and Colleges, Undated. Annual plan. Mimeo. 18 pp., 1983-84.

Government of India. Report of committee on forest and tribals in India. Ministry of Home Affairs, New Delhi. 122 pp., 1982.

Government of India. Recommendations regarding the revision of the National Forest Policy. Department of Environment, New Delhi. 19 pp., 1983.

Gupta, K.M. and Y.C. Bahuguna. Chipko Movement—Its Genesis and Purpose. In: Gupta, K.M. and D. Bandhu (eds.), *Man and Forest—A New Dimension in the Himalaya.* Today and Tomorrow Publishers, New Delhi, 294–300, 1982.

Gupta, R., P. Bannerji and A. Galeria. Tribal unrest and forestry management in Bihar. Indian Institute of Management, Ahmedabad. 89 pp., 1981.

Himachal Pradesh Krishi Vishva Vidyalaya, Department of Forestry, Nauni, Solan, Himachal Pradesh. Annual research report, pp. 99 plus appendices 1981-82.

International Crops Research Institute for the Semi-Arid Tropics. Research highlights. Hyderabad. 44 pp., 1982.

Joshi, D., D. Seckler and B.C. Jain. Social forestry, wood gasifiers and irrigation: A synergistic relationship. Discussion Paper No. 3, Ford Foundation, New Delhi. 18 pp., 1983.

Kapoor, S.L. and R. Mitra. Herbal drugs in Indian pharmaceutical Industry. National Botanical Research Institute. 85 pp., 1979.

Khosla, P.K. Place of forestry education in agricultural universities. Paper for the 12th Convention of the Indian Agricultural Universities Association. 43 pp., 1983.

Khosla, P.K. (ed.), Improvement of forest biomass. Indian Society of Tree Scientists: Solan. 472 pp., 1982.

Khosla, P.K. Agroforestry resources in Western Himalaya. Summer Institute in Agroforestry in the Western Himalaya. Department of Forestry, Himachal Pradesh Krishi Vishva Vidyalaya, S.N.S. Nagar, Solan, H.P. 78 pp. + appendices, 1983.

Khoshoo, T.N. Energy from plants: Problems and prospects. Presidential Address, Indian Science Congress, Mysore, 112 pp., 1982.

Ministry of Agriculture, Government of India, Annual Report, 165 pp., 1982-83.

National Academy of Sciences. Underexploited tropical plants with promising economic value, Washington, D.C., 189 pp., 1975.

National Academy of Sciences. Leucaena. Promising forage and tree crōp for the tropics. Washington, 115 pp., 1977.

National Academy of Sciences. Tropical Legumes, resources for the future. Washington, D.C., 331 pp., 1979.

National Academy of Sciences. Firewood crops: Shrubs and tree species for energy production. Washington. 237 pp., 1980.

National Botanical Research Institute. Annual report, Lucknow. 113 pp., 1981.

National Botanical Research Institute, Lucknow, Brochure, 41 pp., 1979.

Raintree, J.B. A diagnostic approach to Agroforestry Design. International Symposium on Strategies and Designs for Afforestation, Reforestation and Tree Planting, Hindeloord, Wageningen. Sept. 19–23, ICRAF. 22 pp. + tables, 1983.

Ramachandran, P.G. Forestry—India 1981. A historical and current sector review. *OPTIMA*, New Delhi, 55 pp. + appendices, 1981.

Society for Promotion of Wastelands Development. Brochure, 12 pp., 1981.

Werner, F. Indo-Swedish Forestry Programme ii. 1982–83 to 1986-87. Background document. Swedish Embassy, Department Cooperation Office, New Delhi. 92 pp., 1982.

Willey, R.W., B.A. Krantz, M.R. Rao, M.S. Reddy, M. Natarajan and L.P.A. Oyen. Cropping systems research at ICRISAT. Mimeo. 4 pp., 1977.

Williams, J.T., C. Lamoueux and Wulijarni-Soetjipto (eds.). Plant genetic resources of Southeast Asia. National Biological Institute, Bogor, Indonesia, 1975.

World Bank/USAID/ODA. Unpublished draft. India—forestry education, training, research and extension Subsector review. 46 pp. + appendices.

Xavier Institute of Social Service, Ranchi. Postgraduate diploma course in rural development. Handbook, 9th edition, 61 pp., 1983.

Xavier Institute of Social Service, Ranchi. Postgraduate diploma course in social service with specialization in personnel management and industrial relations. Handbook. 16th Edition. 68 pp., 1983.

Xavier Institute of Social Service, Extension programs, Ranchi. 14 pp., 1983.

13

Watershed Management in the Indian Himalaya

K.G. Tejwani

Introduction

Realizing that the Himalaya, yield life giving water, Indians sanctified them, as well as the rivers emerging from them and built their entire civilization round the Himalaya and the rivers.

However, currently the condition of the Indian Himalaya as well as the rivers emerging from them is deplorable. The mountains have been misused, mismanaged and abused so much, that they are virtually "coming down". This is proved by the fact that India has the "dubious" distinction of having its three main river basins—namely Kosi, Damodar and Ganga—carrying and delivering the highest sediment load in the world.

This paper, attempts to review:

(1) What has gone wrong; (2) Why it has gone wrong; (3) Whether it is possible to correct the wrong; (4) What is being done to correct this wrong and whether it is enough; and (5) The policy issues involved for better and faster results.

Biophysical and Socio-economic Environment

The Indian Himalaya are divided into three transverse zones from West to East namely:

1) The Western Himalaya consisting of the states of Jammu and Kashmir and Himachal Pradesh.

2) Central Himalaya consisting of Garhwal and Kumaon Regions of Uttar Pradesh state, and

3) North-eastern Himalaya consisting of Sikkim state, Darjeeling district of West Bengal state, union territory of Arunachal Pradesh, north–eastern hills of Assam state (North Cachar and Mikir hill districts), Nagaland, Manipur, Tripura states and the union territory of Mizoram.

CLIMATE

While the Himalaya largely determine the climate of the Indian subcontinent, they also create their own climate. The climate changes from tropical to alpine within a short horizontal distance from south to north. Four climatic zones ane recognized.

1) moist tropical,
2) sub-tropical,
3) montane temperate, and
4) alpine.

There are marked differences in respect of rainfall and temperature not only between the zones but also within the aspects and valleys within the zones.

MAJOR RIVER SYSTEMS

The Himalaya are the source of three major river systems namely the Indus, the Ganga and the Brahmaputra. According to assessments made by the Irrigation Commission of a total utilizable surface water resource of 666 milliard cu. m (540 MAF) in India about 36.8 per cent accounted for by these three river systems.

POPULATION

According to the 1981 Census, the population of the Himalayan region in India is 23.15 million accounting for 3.4 per cent of the total population. The population of the entire Indian Himalayan region increased by 30 per cent during the decade 1971–81. The population is rural and agrarian in character (Census of India 1982).

LIVESTOCK

In terms of cattle units, over 27 million cattle units are supported by the system. On an average, there are 1.12 cattle units for each human being. (Planning Commission 1982b).

LAND USE

Statistics of land use in Himalaya (Planning Commission, 1982a) show that on an average (1) 53.2 per cent of the reporting area is forest land under the control of forest departments. The area under forest varies from 8.3 per cent in Meghalaya to 91.3 per cent in Arunachal Pradesh. (2) 35.8 per cent of the reporting area is not available for cultivation and 11 per cent of the area is cultivated.

Forest: Though large areas of land are forest land, it does not necessarily mean that they are forested; for example in the Uttar Pradesh hill districts:

1) 10,286.74 sq km of forest land, not in the control of forest department, may be generally assumed to be either completely devoid of forest or supporting very degraded forest cover.

2) Only 58 per cent of the forest under the control of forest department is exploitable; presuming that unworkable forest is also good forest, the total good forest is only 67 per cent inferior degraded forest is 15 per cent and land unfit to grow trees is 18 per cent.

3) The combined inferior/degraded forest in the Uttar Pradesh hills both within the control and outside of the control of forest department is 40 per cent. This is indeed a very unsatisfactory and disturbing position with respect to the forest resource base and the ecological situation in the Himalaya in Uttar Pradesh.

Agriculture: According to the land capability classification, there is no class I and II land, little class III land and some class IV land. As a consequence large areas of class VI and VII land are used for cultivation. Since, only irrigated land is properly bench terraced, the land is grossly mismanaged.

Grasslands: The condition of the grazing lands and the grasslands is fair to poor at all altitudinal zones. It is generally believed that in extensive areas of the Himalaya livestock are in excess of the carrying capacity of the land under the present management systems. However, no direct evidence is available on the matter.

Shifting cultivation is another problem of misuse and mismanagement of land–water–vegetation. Shifting cultivation is practiced extensively in the north–eastern Himalayan zone. The estimates of area under shifting cultivation (1974), indicate that of the total area of 2.7 million ha available for shifting cultivation, about 16.8 per cent is cultivated at one point in time, while the rest is left fallow. Currently the fallow period is 5–7 years, which is insufficient for natural regeneration, hence shifting cultivation is a source of watershed and environment degradation.

Factors Affecting Watershed Degradation

The primary physical factors which accelerate the degradation of watersheds in the Indian Himalaya are the misuse and mismanagement of land by humans.

In recent times the increasing pace of developmental activities such as mining, quarrying, road construction and power transmission towers (constructed unscientifically without consideration for conservation and environment have contributed to the degradation of watersheds.

Among the secondary factors may be included high pressure of human and livestock population.

Given, the human and livestock pressures, subsidiary factors like steepness and length of slope, geological features and climate operate intensively and contribute to very high rates of erosion, run–off degradation (Tejwani, 1984a and b).

What Has Gone Wrong?

The consequences of mountain watershed degradation are, very pervasive and pernicious. They affect adversely the functioning of natural ecosystems (ecological impacts), the production base, goods and services (economic impacts) and the life of the people (social impacts). These adverse impacts include loss of soil fertility, (Khybri et al., 1982); sedimentation of reservoirs (Gupta, 1975, 1980; Sinha, 1984 a and b CBIP, 1981; Murthy, 1981) and irrigation systems (Sinha 1984 a and b), flooding (and associated losses); loss of water resources, loss of inland water transport potential, landslides and land slips (with associated damage to property, lines of communication and life) (Bansal and Mathur, 1976); reduction in, and uncertainty of hydropower generation, loss of inland fish and fish breeding grounds and general deterioration of the quality of life.

Is the Current Land Use System Sustainable?

Not much direct evidence is available as to whether the current land use systems in the Himalaya are sustainable. Mostly, there are reasonable "guesstimates" or "perceptions" of knowledgeable persons that, in general, indicate that the land use system according to the current state of development is not in a position to sustain the population—both of humans and animals. In a case study of a 158 ha watershed (GBPUAT, 1982) it was estimated that to make this watershed sustainable it will be necessary to transfer 50 ha of forest land (from the present area of 93 ha under forest) to the village common land (currently 30 ha). This is a very simplistic approach as it does not reach beyond maintaining the current system. With application of soil and water conservation measures, with water resource development and irrigation, with use of high yielding varieties and plant protection measures, with better techniques of grassland development, and afforestation and plantation management, and better animal husbandry practices and horticulture the system could be made to produce more and be sustainable for current and near future population pressures. However, this is in the realm of conjecture since no such attempt has been made so far.

HISTORICAL PERSPECTIVE

Watershed management is not new, since India has developed and used tanks and ponds for centuries on an extensive scale to harvest water from watersheds, store and re-cycle it for crop growth. An awareness of the problem of sedimentation of tanks has been prevalent as evidenced by the fact that desilting operations were carried out regularly—sometimes enjoined by religious practice—sometimes by social practice and—sometimes by political system. We have been aware of the soil and moisture conservation for crop production in the dry lands for a long time, as evidenced by the extensive traditional practices of field bunding and cultural operations to conserve soil and moisture.

The problems of erosion and land degradation received government's attention as early as the late nineteenth and early twentieth century. A scheme on gully control was implemented in 1920. A research project on dry farming with major emphasis on soil and water conservation was initiated in the thirties.

Current Programmes

After Independence, when planning for development was initiated, soil and water conservation programmes, research and training activities were sagaciously provided in the First Five Year Plan (1951–56). This action is very remarkable. However, while soil and water conservation must be done on a watershed basis, the emphasis was more on agricultural lands. Gradually the agricultural development programmes themselves have evolved with emphasis on watershed management and include other land uses.

A close scrutiny of the agricultural development programmes reveals that emphasis on watershed management has been placed since 1974 with the start of the drought area development programme.

Apart from soil and water conservation programmes, forestry programmes were also initiated during the First Five Year Plan.

Up to 1984-85, 29.4 million ha of land was treated with soil and water conservation measures and in 1980-81, 3.56 million ha were afforested. However, it was realized before the end of the Second Plan, that there was an urgent need to pay attention to the reduction of sedimentation rates of reservoirs. Catchment treatment programmes were therefore started from the Third Plan (1961–1966) onwards.

Since the start of the Sixth Plan not only the entire soil and water conservation programme but also the agricultural development programmes have been firmly based on the concept of watershed management.

Since watershed management is concerned with all land uses within the watershed, to that extent it is a part of integrated rural development in the mountain ecosystems. For the sake of defining the scope of the outlays and achievements, integrated rural development may be allocated to the following areas of action.

Natural Resource Base: To include watershed management. Land use, soil conservation, water resource development, and sediment control.

Input Base: To include hill agriculture, animal husbandry, horticulture, irrigation, seeds, fertilizers, and pesticides.

Infrastructure Base: Rural development education, health, roads, rural electrification, drinking water supply and village industries.

Human Resource Base: Human resource development to include education, training, and employment.

Need Base: Energy, nutrition, food.

It is obvious that there will be an overlap between the above five areas of action under integrated rural development programmes. This is how it should be. However, except for the overlap or interface relationships (like sedimentation being influenced by roads and electrification) watershed management for the purpose of this paper will include the activities identified as above. While investments have been made and programmes implemented in soil and water conservation with the start of the First Plan, it was not until the Sixth Plan (1980–85) that a *National Policy was Adopted to Use Watersheds as a Units of Land and Water Resource Development.*

ACHIEVEMENTS

Central Sector/Centrally Sponsored Schemes

These schemes are initiated, and funded by the central government and in some cases also implemented by them. They serve as pilot projects to test solutions of different problems, to serve as catalytic agents to support essential activities of national importance.

Central Sector Schemes

Delineation of priority watersheds: The term "priority" watershed means that a watershed in a river valley project (RVP) or flood prone river catchment (FPC) is in urgent need of treatment either to reduce sediment or reduce run-off. Himalayan RVP catchments have an area of 52,000 sq km of which 31,800 sq km have been covered, (representing 61 per cent of the total catchment areas). As many as 13,400 sq km of catchment area surveyed have been identified to be very high, and high priority watersheds; only 31 per cent of the catchment areas surveyed have low, and very low priority categories (Das et al., 1981).

Pilot Project for Control of Shifting Cultivation: The scheme was initiated in 1977-78 in six states (Andhra Pradesh, Assam, Meghalaya, Nagaland, Orissa and Tripura) and by 1978-79, an area of 1800 ha had been developed and 900 families settled. After this scheme was transferred to the states, two union territories—Arunachal Pradesh and Mizoram—had by 1983-84, settled 1400 families and developed 2,800 ha of land. The programme included developing and allocating 2 ha of land for subsequent allotment to each beneficiary family.

Centrally Sponsored Schemes

A scheme on soil and water conservation in the catchment of river valley projects has been operational since 1961 (the start of the Third Plan). This scheme at present operates in 31 river valley projects. To the end of 1984-85, 2,707,110 ha of land had been treated in the seven Himalayan river valley projects. It is noteworthy that the pace of treatment has increased with each plan. In the Sixth Plan 504,000 ha were treated as compared to the total of 203,110 ha treated up to 1979-80, a span of 19 years.

State Sector

Soil and water conservation programmes were taken up in the First Plan and have been expanding in scope and activities with each successive plan. These programmes are undertaken by the state Departments of Agriculture, Forests and Irrigation. Apart from *bunding* and terracing of agricultural lands undertaken earlier, at present there is integrated, multi-treatment on a watershed basis. On the non-agricultural lands tree plantation programmes are undertaken. Attention is paid to water resource development and conservation and sediment control by programmes such as *nala bunding*, check dams, gully plugging, land shaping, percolation tanks, water harvesting, and water conveyance. Up to 1984-85, a total land area of 27.07 million ha has been treated. In addition 2.31 million ha was treated under the central sector.

The achievements of state sector soil conservation programmes for the Himalayan states are available as at 1982-83 when 324,360 ha had been treated. (These statistics exclude the areas treated in the hill districts of West Bengal and Assam). During the Sixth Plan, the physical achievements made a quantum jump. For example at the end of the Sixth Plan, the area treated in the hill districts of UP was 130,360 ha as compared to 31,230 ha in the period 1979-80. This is true of all states.

Development of springs, construction of tanks and water conveyance channels, undertaken under the privately implemented irrigation programmes, with the support of the government may legitimately be considered an activity contributing to, and depending on resource conservation. Springs depend on the conservation of water. Development of irrigation potential normally leads to improvements of bench terraces. For example in Uttar Pradesh during the Fifth and Sixth Plan potential for irrigating 35,810 ha and 68,840 ha of land respectively was created by the private sector while the state government created a potential of irrigating 22,650 ha and 33,620 ha respectively. In the Fifth Plan 6033 km of channels for irrigation were constructed through minor irrigation programmes (UP Government 1985).

Road construction, vital for the overall development of the hill regions, generally contributes to very severe erosion. In fact the roads, unscientifically constructed in the hills, have proved to be a mixed blessing. The dimension of road construction is an indicator of the dimensions of watershed restoration and rehabilitation needs. During the Fifth Plan and annual plan 1979-80, a total of 3282 km of roads were constructed (UP Government 1985). One can be certain that these are sore spots contributing to erosion and sediment generation.

FORESTRY

From 1951 to 1980, India has invested Rs. 1,28,690 million in agriculture and allied programmes, (34.1 per cent on agriculture and land reforms, 18.8 per cent on forestry). If it is remembered that in earlier plans the intention of the planners was to create an infrastructure for increasing food production, it is easy to rationalize the priorities of investment. However, compared to 47 per cent of land being under agriculture, 23 per cent of land is also under forests and the country needs fuel wood and timber, investments in the forestry sector have been low. It is indeed remarkable to note that until 1980, India has actually invested more in soil and water conservation than in the forestry sector. In the Sixth Plan a quantum jump has been provided to investment in the forestry sector, Rs. 6925 million as compared to the investment of Rs. 4839 million in the preceding 20 years.

It may be desirable to make mention of the centrally sponsored scheme of SOILWATCH (Soil, Water, Tree Conservation in Himalaya) started in the Fifth Plan. In the Sixth Plan Rs. 250 million were provided. The scheme is a reflection on the special concern by India for the ecological security of the Himalaya.

Among the Himalayan states, Uttar Pradesh had invested Rs. 25.07 million in the Fifth Plan, Rs. 5.16 million in the 1979-80 annual plan and Rs. 109.13 million in the Sixth Plan. During the same periods it had afforested 26,060 ha, 5,700 ha and 34,460 ha respectively. Thus the pattern of investment and achievement were similar to that for the whole of India.

PRESCRIPTION TO PROFIT

It is a recognized fact that watershed management activities (especially soil and water conservation and afforestation) are long-range and long-term benefit programmes. That they conserve soil and water and restore ecological balance is a well known fact. However, in all countries and especially in developing countries which have many other pressing problems to solve the political system looks at short-term gains initially and needs to be convinced and assured that in the case of long-term programmes there will be direct and productive benefits in addition to the indirect benefits.

Sediment Control

It has been observed that there has been a 25.5 per cent reduction in the sedimentation rate in Bhakra Reservoir (Das et al., 1981) and 23 per cent reduction in the rate of sedimentation in Ramganga catchment (Gupta, 1980).

Both these reservoirs have their catchments in the Himalaya. However, reduction has also been observed in other reservoirs having their catchments outside the Himalaya. While these reductions in rates of sedimentation are welcome they are currently not fully satisfying for various reasons:

1) The observed rates of sedimentation in the reservoirs were 200 per cent more than the designed inflows. Further, contrary to the belief that all sediment will be deposited in dead storage, the sediment has become deposited in both dead as well as live storage (Sinha, 1984a; CBIP, 1981).

2) The treatment of river valley catchments after construction of the reservoir is at best a remedial measure. There is a need of preventive measures before the reservoir is filled, and this approach has perhaps more economic advantages as will be discussed later.

Direct Benefits

Direct benefits of soil and water conservation are marketable commodities such as food, fuel, fodder, fruits, fibres and clean water. Although evaluation data of entire watershed management projects are not available, information of individual components of programmes is available from research studies. For example:

— It is reported that in a sub-mountain high rainfall area an unlined embankment type of farm pond constructed for run-off storage and recycling, apart from the indirect benefits, had the direct benefit of making available water for irrigation; it had a benefit/cost ratio of 1.85 and 1.96 over a period of 30 and 50 years respectively, if, water was applied prior to sowing the crop (Vimalkishor et al., 1980).

— In an experimental watershed management project, soil and water conservation was tested in all the land uses. The overall benefit/cost (b/c) ratio was 1.5, while for individual land uses, the b/c ratios varied from 0.92 to 3.6 (Seckler, 1979).

— In a study of the *Hirakund* catchment, small sediment reduction structures were evaluated for b/c ratios. These structures, not only retained the runoff and sediment (protective benefit) but also resulted in reclamation of land for irrigation and a consequential increase in crop production and employment generation. The area treated was 2321 ha in eight years, area reclaimed for cultivation was 91.4 ha and area irrigated with stored runoff was 546.8 ha (Das and Singh, 1981). The b/c ratios for production purposes were 1.13 and 1.66 over 10 and 20 years respectively; for protective purposes the b/c ratios were 1.19 and 1.48 for 10 and 20 years respectively; the combined production and protective b/c ratios were 2.32 and 3.14 for 10 and 20 years respectively; the post-project and pre-project employment ratios are 2.94 and 2.38 for 10 and 20 years respectively (Das and Singh, 1981).

In the matter of conservation and utilization of lands not suited for agriculture, agroforestry-silvo-pastoral systems are reported to have a b/c ratio varying from 1.05 to 3.43 depending upon the combination of trees/grasses and their spacings (Mathur et al., 1979). With reference to pure plantation of Eucalyptus in degraded and denuded land a b/c ratio of 1.68 has been reported for a nine-year-old plantation; this plantation further had the scope for coppicing and was expected to give a higher b/c ratio as the cost of land clearing and plantation is avoided with coppice (Rambabu et al., 1980). A large number of case studies in other regions reported b/c ratios of direct benefits to be more than 1, for soil and water conservation practices on agricultural lands and plantations; and soil and water conservation activities on non-agricultural lands (Tejwani and Rambabu, 1982).

Indirect Benefits

Apart from the above types of direct benefit, many indirect benefits accrue due to soil and water conservation measures. If soil is conserved, the land continues to produce crops indefinitely; if water is conserved streams flow for longer periods, water is clear and is available for irrigation and drinking; floods are moderated and rates of sedimentation are reduced. These indirect benefits have been experimentally demonstrated. For example:

— Studies conducted in the erodible Shivalik hills have shown that with appropriate soil and water conservation measures the rate of sediment can be reduced from 80 tonnes/ha/annum to 6–7 tonnes/ha/annum within five to six years of treatment (Misra et al., 1975).

— In another study in the same area, as a result of closure, afforestation and gully control measures, peak discharge and total runoff were both reduced by 61 per cent each, six years after the treatments were imposed (Kaushal et al., 1975).

— In a high rainfall sub-montane degraded and denuded area it was observed that when a plantation of Eucalyptus was undertaken after clearing of the watershed, originally covered with brushwood, runoff was reduced by 28 per cent (Mathur et al., 1976).

— Similar positive indirect benefits have been reported from other regions of India (Tejwani and Rambabu, 1982).

Towards Betterment

An objective of betterment within programmes and performances implies prerequisites.
These include a willingness to

1) undertake a critical review of past policies, plans programmes, practices and performances,

2) accept the lapses and be ready to learn,

3) build (without acquiring a sense of complacency) on successes achieved, and

4) ensure improved performance by improved management.

In fact the last prerequisite may be called the key to success as everything then follows.

The strategy in this paper, is to raise the policy issues, review them and indicate a future course of action in view of the lessons learned. In some cases it may be possible to identify the malady but, it may not be possible to identify the remedy. If a remedy is identified then it may not be possible to apply it in some cases for various reasons—social and economic. The policy issues may be divided into social, economic, biophysical and political categories; it may not however, be possible to separate them into watertight compartments as they are not independent but very much interdependent and impinge upon each other. Further policies and issues have been identified—wherever necessary—as a constraint. These issues/constraints have been matched with current activities to indicate the actions taken. Positive aspects of issue have been identified and wherever possible a course of action suggested for betterment. For matter of convenience the issues have been arranged in four categories: national, regional, institutional and technological. Socio-economic considerations are common to all.

NATIONAL ISSUES

Awareness

Awareness of the problem, of the fact that something needs to be done, and that if something is being done, it is to be correctly implemented to achieve the set goals, is perhaps the foremost requirement for resolution of the problems. Regarding land-water-vegetation systems, it is the government, the line sectorial departments socio-political system, people at large, farmers and users of the land who are to become aware, active and responsive.

It can be said that India has been rather fortunate with respect to the awareness of the problems of watershed degradation. At the government level this is evidenced by the extensive development, research and training programmes initiated and implemented.

At the people's level, the "Chipko Movement" in the Himalaya, is a classical example of the awareness of the people—and more so of the women who bear the brunt of farming, fetching fuel, fodder and water—initiating a movement (Kunwar, 1982). This movement has both economic and ecological overtones. People in the Himalaya are also aware of the degradation of the production base and disappearance of water and presumably wish to act. However, perhaps, they are enmeshed in a social-economic-cultural environment, which does not permit them to be effective.

National Land Use Policy

As a consequence of the expressed concerns to have a Nationnl Soils Policy/National Land Use Policy/A National Charter of the Land (Vohra, 1972, 1974, 1975; National Commission of Agriculture, 1976; Tejwani, 1982), the government of India recognized the urgency of the matter and in 1984 constituted:

1) A National Land Use and Waste Land Development Board under the Chairmanship of the Prime Minister.
2) National Land Resources Conservation and Development Commission.

The former is the apex body and the latter bodies are entrusted with the responsibility for formulating policy and for its implementation. It is hoped that a National Land Use Policy will be soon formulated.

Population Pressure

Population continues to grow unabated and at explosive rates in the fragile mountain ecosystem, as well as in the plains. Most of the population is young and if properly mobilized can be an asset. Although a considerable proportion of the population has indicated a capacity to absorb, adapt and benefit from modern technology, there are limits within the system to support an increasing population. Population control is a 'key issue' in the entire development strategy, particularly when dealing with watersheds in fragile mountain ecosystems. If any single programme determines the success or failure of developmental activities it is population control.

REGIONAL ISSUES

Development Strategy

Watershed management, however important in itself, cannot be made a development activity by itself—particularly when large numbers of poor agrarian people are living in the watersheds. Watershed management has to be a part of the development strategy for the Himalayan region. All mountain watersheds in general, and Himalayan watersheds in particular have inherent biophysical and socio-economic constraints which impinge on the pace, quality and growth of development. Constraints identified are:

1) Isolation;
2) Poor infrastructural facilities;
3) The natural system is ecologically fragile and refined efficient management is required for sustained production;
4) A wide variation in agro-ecological conditions within very short distances due to many permutations and combinations of altitude, slope and aspect conditions; and

5) Very limited good agricultural land available which creates a natural barrier to increases in food production.

In recognition of these constraints, a need for specific strategies, for development has been recognized for the Himalaya and hill areas by the government.

Strategies include,

1) All states; parts of states, union territories located in the Himalaya have been recognised as "backward hill areas for special consideration." Guidelines for dealing with backward hill area problems have been provided to states and union territories (Planning Commission, 1981).

2) The Fourth Plan, suggested a multi-directional Area Development approach to accelerate development of backward areas—Himalayan hill areas included.

The Fourth Plan recognized that in hill areas investment is high and returns low, therefore more central assistance was allocated to meet specific needs and problems.

It is noteworthy that development strategy for these backward hill areas included an item "maintaining the ecological balance" (Planning Commission, 1981).

People: Upland/Lowland Relationships

The terms "upland" and "lowland" are used to identify the hills and plains. If the uplanders manage catchments and use water wisely, they obtain good quality and sufficient water for longer periods of time. The lowlander also reaps similar benefits. If the uplander misuses and mismanages catchments the water is polluted (with sediment in the developing countries), the lowlander will have serious problems in resource management, flooding and other cyclic problems.

Every individual wishes to survive. Only when, the individual is assured of survival will other issues be considered.

This fact of life is also applicable to the upland and lowland relationships. The economic security of the uplanders must be perceivably assured and as an outgrowth, they will be persuaded to perceive that their lives are interwoven with the lowlanders. They should perceive that they are equal partners sharing in the development of the hills and the plains. This will not come automatically. The *sine qua non* for this is, that lowlanders must also perceive that their development and growth is intrinsically linked with the uplanders. Once this interdependence, common goals and respective roles are appreciated at policy/decision making/planning/implementing/socio-political levels, the pace of development and growth and commitment to the programmes will be more real. Without this, programmes will be planned and implemented in disparate and disjointed ways and may not necessarily achieve the goals envisaged.

As far as water and forest resources are concerned, it is much more beneficial that their generation, utilization, maintenance and conservation start upstream with benefits flowing downstream for the good of all. It is fortunate that this is realized; what is needed now is its vigorous implementation.

INSTITUTIONAL ISSUES

Research

Since watershed management is a combination of many and varied field techniques it requires strong research, demonstration and technological packages for application in the field.

When soil conservation programmes were included in the First Plan (1951–56) it was obvious to the planners that while the problems of degradation and destruction of the production base were broadly known, solutions supported by scientific investigations were not available. Consequently, a chain of Soil Conservation Research, Demonstration and Training Centres was established during the First and early part of the Second Plan. Two centres were responsible for work in the Siwalik hill region (at Chandigarh) and the Himalayan watersheds (Dehradun). In addition there is an extensive network of universities, central research institutes and centres, state research centres, in the Indian Himalayan regions.

Although each of these units has a specific role for growth and development in the region, more could be contributed if research efforts specifically oriented towards local problems of resource management, utilization and conservation were activated. A number of recommendations for specific areas of research have been made by the Planning Commission (Planning Commission 1982 a) and others.

Training Programmes

Watershed management as a multidisciplinary programme needs skilled technicians/professionals for its implementation. Further, it requires options of alternate land use and structural works needing investment. If the work is incorrectly done, investment is wasted, and great damage is caused by failure of the programmes. It is therefore essential that the work is done by trained, fully oriented and committed personnel.

In the First Plan (1951–56) itself, training of manpower for the development programmes in soil and water conservation was provided for (Tejwani, 1979 b). Regular courses and short-term special courses were established and thousands have been trained. In spite of this massive effort, due to continually expanding watershed management programmes, the technical personnel trained are insufficient (Tejwani, 1981). The lack of trained personnel has been recognized as a major constraint in starting/implementing and reaping better fruits from soil and water conservation (Vohra, 1975; Tejwani, 1979, 1981). These have been overtaken by the anticipated much larger outlays in the

Seventh Plan afforestation programmes. While a lot has been achieved more needs to be done and some estimates have been made (Tejwani, 1981). These have been overtaken by the investment increases anticipated in the Seventh Plan.

Looking Ahead

Are We Catching Up?

It is good to know that the problem of watershed degradation in the Himalaya is recognized and that large scale watershed management/afforestation programmes have been initiated and are being implemented at an increasing pace with each successive plan. However, the issue, which is yet to be addressed, 'is enough being done'?

In spite of all that has been achieved, it can be stated that enough is not being done. It must also be remembered, that apart from afforestation most of the earth work programmes like gully plugs and check dams have a limited useful life of approximately 10 to 15 years. If an area has not been well stabilized some of the works will need to be redone. On balance, currently the rate of degradation is higher than the rate of restoration/afforestation.

In view of this it is imperative that perspective planning is done so that, in the very near future and at least by the Eighth Plan (1991–1995) the pace of improvement is greater than the rate of degradation.

Remedy versus Prevention: Catchment-Reservoir-Command Area System

At present a reservoir is planned and designed assuming *status quo ante* of the catchment. In other words, it is assumed that the inflow of water and the silt charge will continue to be the same in quality and quantity as observed in the past.

It is only subsequent to the project implementation when apprehensions of variations in design assumptions likely to adversely affect the life and stability of the reservoir and structures, are confirmed that remedial measures of catchment treatment are thought of. This is a very shortsighted policy with dangerous consequences.

With the present approach, (1) the country does not get the designed benefits both in quantity and quality from the investments made, (2) the country loses more capital in higher costs of operation, repair and maintenance than originally provided for, (3) the dam sites which are very rare are lost within a shorter life span, and (4) the b/c ratios are never attained, and if costs are realistically allocated the project may infact have negative b/c ratios.

It is imperative and most urgent that a firm policy decision is taken, that hereafter a catchment reservoir command area will be surveyed, planned, designed, constructed and managed at least simultaneously. In fact it may be wiser to plan and implement catchment area programmes in advance of reservoir construction (Tejwani, 1984b). Once this decision is taken, it should not be varied/changed on any account whatsoever. This view is supported by past experiences and it may be more economical and beneficial if we adopt this as a policy.

For example, it has been reported that if soil conservation and watershed management practices are included as a part of the project from planning and design stages, and a 25 per cent silt charge is planned to be reduced, the percentage increase in utilization of water can be 1.48–1.79 and 3.02–3.81 over a design period of 50 and 100 years respectively. In another case study, it was observed that a pre-planned 25 per cent reduction in sediment would help by reducing the height of the dam from 32.6 to 32 m thereby reducing construction costs by 5 to 6 per cent. In addition, there will be less submergence, reduced costs of rehabilitation, reduction in the loss of land resources and forests; and due to less surface area of the reservoir reduced evaporation losses (Sinha, 1984 a, b).

Funds are made available for catchment treatment and programmes are undertaken but often they are commenced either too late or indifferently. What needs to be done is to include them at the planning and design stage. The adage 'a stitch in time saves nine' is very apt in this case.

Institutions Coordination versus Integration

Watershed management is a multi-disciplinary programme involving many disciplines. Some states have separate soil conservation departments, some undertake work through Agriculture and/or Forest Departments. As work in watershed management grains momentum, the issue often arises as to how to coordinate/integrate the work of different departments.

This issue is discussed here with respect to the allocation of responsibility (and therefore funds) and ensuring that the work is undertaken in a concentrated way in the same watersheds.

There is a consensus of opinion that as line departments in the states have been long established and have many other functions to perform, it is better that they continue to function independently. However, in respect of watershed management programmes, they should attend to all the activities and establish within themselves a competence to work on all land uses. This approach is possible and has been resolved where programmes are large as in Uttar Pradesh, Jammu and Kashmir and Himachal Pradesh.

If a decision is made that each department will implement its sectorial activities, it becomes imperative that all related departments coordinate their work in the same watershed simultaneously, in order to complete the work watershed by watershed and achieve effective results.

If a separate department for soil and water conservation is created, it must develop 'in house' competence to deal with all components of the programme.

There are other issues of coordination between Agriculture, Forest, Roads, Electricity, and Irrigation Departments. It is common knowledge that

Forest/Irrigation Departments and also people by their activities cause damage to roads; Roads/Power Departments cause damage to plantations, water courses and bench terraces undertaken by the other departments. As everyone goes about merrily on their own sectorial pursuits, on balance, perhaps in some situations more damage is caused than good. It is obvious that there is great need and urgency for cooperation and coordination between various departments.

Who Pays for the Work and How Much?

In the short-term soil conservation and afforestation works do not pay immediate returns neither to the farmer nor to the community. Often, the benefits may accrue away from the site and also may be indirect. It is however necessary that the investments be made. The issues then are: (1) who pays, (2) if a farmer or individual in the upland watershed is to pay then for which type(s) of work should he pay and how much should he pay, and (3) what are the obligations of the people who live in the plains towards supporting the upland watershed programmes? Do they pay directly?

This issue was also raised in a general way in upland-lowland relationships. However, this issue needs to be raised more specifically with respect to the allocation of financial resources and expenditures. This is also related to incentives for the beneficiaries. Fortunately, it has been realized and accepted in India, that since soil and water conservation works, have social benefits—indirect, off-site and long term—the upland beneficiaries may not be required to pay entirely for the work. Currently the subsidies/incentives vary between 25 per cent and 100 per cent.

With respect to the contributions from the plains for restoration and maintenance of upland watersheds, there is an excellent example from Colombia where a percentage income from power generation (4 per cent) is transferred to rehabilitation and development of watersheds. This mechanism needs to be explored/experimented/adapted.

People's Participation

If it is enquired from a development/extension worker, a researcher, a policy maker, or a social worker, as to what is implied by, and what is the scope of 'people's participation' the invariable response will be that it implies a participatory role by the beneficiaries/farmers and sometimes by women. However, this definition of 'people's participation' camouflages the issue and often results in disastrous consequences, since, the focus is placed only on the group of beneficiaries/farmers/women at the grass roots level. To some extent it is a safety valve provided by other groups to divert attention from themselves. However, if we ask the same question from the beneficiaries/farmers/women, we will indeed be surprised to hear that in their opinion in addition to themselves, all others starting from the top (the policy/decision maker) to the lowest rung on the ladder (the official functionary/social worker) are participants and by implication 'people'. The issue in fact is that 'people's participation' should encompass all those concerned with policy/decision making processes, project formulation/implementation, technocrats, managers, middle level/field level technicians, the socio-political system, the community at large and of course the beneficiaries/farmers and women.

The issue of the participatory role of all people from the highest to the lowest level is very crucial to the successful initiation/design/financing/implementation of development programmes. Examples where a key person at the policy level gives a firm direction to generate programmes or where the lowest functionary makes a programme succeed (even though the programme is faulty in design) are well recognized.

At the lowest level the failures come to our notice yet the successes achieved by individuals under great odds are not recognised but the people who benefit do remember.

It is neither possible nor desirable to review the role or commitment of each participant of watershed programmes in the Himalaya, but it may be worth while to highlight a few examples.

Neither a beneficiary/farmer will change land use patterns or a practice on which he is subsisting, unless he perceives that the proposed change will benefit him directly and immediately. For example, he will not accept erosion control measures and pay for them because they do not benefit him directly and immediately; he will not plant or protect grasses and trees on village common land since he is not sure of his share. (However, the other contributing factor in this case is that he gets free grass, fodder and fuel from the reserved forest. He does not consider his labour spent on collection from long distances as a loss, since in his world labour does not have a cost). On the other hand, if there is a project for provision of irrigation water, then not only is he willing to participate in the project by way of providing labour, borrowing money to pay for part of the work, but he is also very willing to improve his own bench terraces.

Project level technicians: For transfer of the technological package it is imperative that project staff are technically competent and sensitive to the needs of watershed management as well as being sensitive to the needs, urges and motivations of the local people. The project staff have to be committed and oriented to doing the job well and on time. A defective job (like wrong disposal of surplus water or wrong alignment of a gully plug/check dam) is likely to cause more damage to the whole programme than any amount of publicity or funds. Keeping to schedule is also relevant since terracing and all earthwork jobs have obviously to be completed before the onset of rains or sowing of crops. A farmer cannot afford to loose a crop season. If seeds, seedlings and fertilizers have to be supplied, they have to be on-site at the time of sowing/planting/application. These situations are not imaginary but facts of life. Failure to perform work on time turns the farmers away and then to later claim that the people did not participate is a travesity of truth. As far as the field technicians are concerned the farmers are their 'clients', and the staff must be motivated by a sense of trusteeship and commitment. The subject of professional competence is dealt with in the part on training programmes).

Supervisors/Managers: Apart from being professionally competent, committed, sensitive and sympathetic to the beneficiaries, they need to provide leadership and guidance to their staff. Leadership is acquired/respected among professionals by professional competence. A professional supervisor should be competent to resolve technical issues. A supervisor at any level, has to be obviously sensitive to the needs and motivations of his/her staff. These two abilities are the *sine qua non* of a successful supervisor.

Project Director/Technocrats/Decision Makers: This group of people who share the responsibility of (1) project identification, formulation, implementation, evaluation, (2) convincing and selling the programmes at the policy and political levels, and (3) dealing with a large number of staff, laying down targets, providing/arranging funds and inputs on time and providing a congenial environment for the success of their staff.

Of course, they need different skills but the basic inputs of professional competence, commitment to the job/programme/cause and sensitiveness to the needs and motivation of their large staff are a *sine qua non* of the success of the project and the programme. These prerequisites may appear to be obvious, but often it is the obvious which is lost sight of. Professionally competent people or committed people do not just happen—they are created. This aspect is dealt with separately under training and R & D efforts.

Legislation

Legislative authority to enact legislation on land and water lies with individual states. Consequently, the Indian Parliament cannot enact a legislation on soil and water conservation. In order to enthuse, encourage and support the state governments to enact such legislation, the central government formulated a 'Model Conservation Bill' in 1955 and circulated it to the states. Sixteen states and union territories have legislation relating to soil conservation (Jacob, 1981). In some states soil conservation measures are implemented under earlier existing statutes like the Bombay Land Improvement Act (1953) and Madras Land Improvement Schemes Act (1949).

The same is the case with the Forest Act. As a sequel to the recommendations of the National Commission on Agriculture (1976) a Central Forestry Commission was established to formulate a model bill of forests for eventual adoption by the states, since the subject of 'forests' was also in the states legislative jurisdiction. Amendments incorporated place the subject of 'forests' in the Concurrent List, confirming the jurisdiction of the central government to also enact legislation. As a consequence a new draft of the Forest Act has now been prepared for enactment by Parliament.

With the changing socio-economic conditions, the soil and water conservation programmes, watershed management programmes, afforestation, social/community/farm forestry programmes, have acquired an urgency. Hence there is need of new legislative approaches and initiatives. Policy initiatives regarding land use and forestry are anticipated and new legislation may be forthcoming in the near future.

TECHNOLOGICAL ISSUES

Agricultural Land: Misuse

Even though the land capability classification, currently in vogue, indicates that the land suited for agriculture (mainly class III and IV lands) is a minor fraction of the total land area, yet the land which is actually cultivated is much more. It is obvious, that either the land is grossly misused or the specifications for land capability classifications need revision. What are the options?

With respect to the land capability classification system, there is not much leeway as there are physical and economic limitations to cultivation of steep slopes beyond a certain limit.

The other options are to:

—Bench terrace the land properly,

—irrigate as much as is possible,

—use inputs of modern technology for rain-fed and irrigated farming,

—diversify by growing high value (preferably low volume) crops such as vegetable and flower seeds, fruits and vegetables.

However growing fruits is in itself fraught with dangers of deforestation as observed in Himachal Pradesh. An estimated shortage of 49482 cu m of wood for making packing boxes was observed (Swarup and Sikka, 1983). Wood for packing boxes is at present highly subsidized and the issue of wood for packing at subsidized rates leads to destruction of forests. There has long been awareness of the problem which fortunately is now being resolved with alternative sources of packaging. This example emphasizes two lessons that are very good examples of two aspects of the same problem:

1) it is desirable to analyse the whole system and anticipate problems and resolve them

2) it is wise to be aware of the evolving issues/problems and intervene quickly as and when the situation arises.

Agricultural Land: Mismanagement Fragmentation

The size of farm holdings is very small, 70 per cent of holdings are less than 1 ha and only 13 per cent are more than 2 ha. These small holdings are fragmented and therefore at many locations (as many as 13.5 locations per holding). At each location there is more than one field per farm. (Each location can have as many as four fields) (Shah, 1981a; Ghildyal, 1981).

Given this scenario, how can a farmer be expected to construct terraces, provide irrigation and attempt high inputs. The situation will baffle the best of us. It is remarkable that the farmers are managing these fields and surviving.

The obvious approach is to consolidate the holdings. However, the situation is not as simple as it appears. There are many biophysical handicaps (like fields being at different elevations, terraced/unterraced, rainfed/irrigated, near the water source/away from water source) and legal difficulties.

The issue is complex, interactable and hence remains unresolved! It cannot be resolved within the present form and current farming systems.

The solution may lie in the development and growth of other sectors so that the population is weaned away from the land.

Forest Land

About 50 per cent of the land in the Himalaya is under the control of the government Forest Departments, but it is not necessarily forested land. For example in Uttar Pradesh only 60 per cent of land under the control of the Forest Department in the hills is forested. Forty per cent of this forest is degraded or inferior. The issue is how to forest it and make it produce goods and services on a sustained basis.

Considering the pressures on forest land, it is indeed remarkable that the forest department has succeeded in protecting some forests. However, having said this, there is no reason why Forest Departments, should not be able to afforest and increase the area under forests. This is practical and feasible as technologies are available and land in large continuous blocks is also available and under the control of the government. The emphasis should be on an increased pace of afforestation and a sense of a job *well done* from start to finish. The achievement criterion should not be 'area planted' but 'area planted and made to produce'.

Common Lands

Common lands are provided to villages to meet grazing, timber and fuelwood needs. In land use statistics they are reported as 'Area not available for cultivation' and 'Area other than cultivated and excluding fallow'. In addition, particularly in the Uttar Pradesh hill districts there are forest lands given to the revenue authorities as well as Panchayats for use by the people. (These lands account for as much as 30 per cent of the total forest land in the Uttar Pradesh hills). The condition of these common lands is deplorable. In Uttar Pradesh, the originally allotted forest lands to the revenue authorities or Panchayats do not contain forest and these as well as other lands do not grow sufficient grass to support cattle. These lands are highly degraded and are a source of sediment and cause of damage (due to gullying) to neighbouring fields, water courses, roads and property. The extent of damage done is to be seen to be believed.

These lands *per se* are suited for supporting good grass cover and tree growth. There is indigenous grass/bush/tree flora, which if given the opportunity to grow naturally, will provide good quality and quantity of grazing. The problem does not relate to the capability of the land to provide goods and services for which it is suited. The basic problem is management. Stone wall fencing/barbed wire fencing have been tried to assist growth of grass/tree species. Yet, it is easy to break them, which in fact is the rule rather than exception with the result that there is infructuous expenditure, respect for the rules/regulations/discipline is lost and it is difficult afterwards to reintroduce other regulatory functions. There is no other solution in a democratic society except that the people themselves provide a 'social Fencing' and regulate the use of this common resource. The issue is how to achieve this? Can sociology resolve it, not in theory but in practice? Can a social worker or NGO achieve this constructive goal?

Carrying Capacity

There is no direct evidence as to whether the carrying capacity of the land in the Indian Himalaya has been exceeded. However, there is general circumstantial and observational evidence. The situation is also not uniform throughout the Himalayan region. It would appear that the situation is very critical in the Uttar Pradesh Himalaya and not critical in Arunachal Pradesh. Sikkim state could be considered as within the carrying capacity of the land. Other states fit at various levels between these two extremes. However, it is clear that in the entire region where man has intervened, there are pockets where the carrying capacity has been exceeded. To that extent the entire Himalayan ecosystem in India, either extensively (as in Uttar Pradesh) or locally is subject to stress and strain. What are the options?

The options to meet the challenge of exceeding the carrying capacity are rather limited. For example, the issue of restricting human and cattle populations has already been discussed and it is indicated that this needs to be firmly managed. A suggestion has been made by some to transfer forest land to the villages for agricultural and non-agricultural production. This is an approach of horizontal expansion. First of all, as a policy decision, it is a very dangerous suggestion as whatever little forest is left, may also be lost. Secondly, there is no guarantee that production will increase. There is every likelihood that the fate of this transferred land will also be the same as that of the other common lands.

A third option is the migration of the people. Whatever is possible and whosoever is able to do so does migrate to take a chance elsewhere. There is no land available in India either within the Himalaya or on the plains. So the only option left is to optimise the land use and increase its productivity on a sustained basis in conjuction with population control.

Transport System: Roads

If currently any single source of sediment generation, unstability of hill slopes, cause of land slides (man-made), erosion and gullying and forest degradation is to be identified, it will be generally agreed that it is the vast network of roads which has been made in the Indian Himalaya. If it is so, the question which could be legitimately asked is, 'Was a mistake made to construct these roads?' The answer will be an emphatic denial. The extensive network of Himalayan roads has been a mixed blessing. It has been necessary for development which has taken place in the hills as well as the plains; thus it has provided 'Development Opportunities'. On the other if has been also termed as a 'Development Disaster'.

Considering the fact that these roads were made in a hurry, the lack of attention to ecological considerations was understandable in the sixties and seventies. However, since the late seventies we have been concerned about the problem—not of ecological degradation, sedimentation or loss of production base, but of the enormous cost involved in maintaining them. Even in the eighties the correct lessons have not been learned. The techniques and technologies of aligning and constructing roads on a scientific basis and stabilizing the slopes are well known.

The issues are not technological but socio-economic and political. People want roads and politicians want to tell the voters that it was they who got the roads for them. Financially, money is allotted for road construction without any consideration or allocation for conservation and stabilization works. Further, the road alignment is changed to suit the 'convenience' of those concerned. In the process a road is made which causes damage and costs more in maintenance, than if it had been made with clear adherence to scientific principles. Ultimately, perhaps everyone would have got a more efficient and functional road and possibly at the same or less cost.

Not that these facts are not known. They are widely known, discussed and debated (Planning Commission, 1982 a). What is needed is action which ensures that with the given allocations for road construction, roads are aligned and made on scientific principles that include provisions for drainage, and slope stabilization. This may not have been possible earlier but is certainly possible in the eighties and in the future. It calls for managerial and political will.

Functioning of roads, however, scientifically and efficiently constructed and maintained is also related with how the land surroundings are used. The best of roads can easily be damaged/destroyed with consequent cyclical ecological disturbances if the surrounding forest land, grazing land etc. is not properly used.

REFERENCES

Bansal, R.C. and H.N. Mathur. Landslides—the nightmare of hill roads. *Soil Conserv. Digest* 4 (1): 36–37, 1976.

Census of India, Primary census abstract. General Population Series 1 Part II B (1). Census Commission of India. Publisher: Controller of Publications, Civil Lines Delhi, India, 1982.

CBIP. Central Board of Irrigation and Power. Sedimentation Studies in reservoirs. Technical Report No. 20 Vol. II, New Delhi, 1981.

CSWCRTI. Central Soil and Water Conservation Research and Training Institute. Report on operational Research project. *Watershed Management*. Dehradun, India, 1981.

Das, D.C., Y.P. Bali and R.N. Kaul. Soil conservation in multipurpose river valley catchments, Problems, programme approaches and effectiveness. *Indian J. Soil. Conserv.* 7 (1): 8–24, 1981.

Das, D.C. and S. Singh. Small storage works for erosion control and catchment improvement: mini case studies. Soil Conservation: Problems and Prospects, John Wiley and Sons, Chichester (Ed. R.P.C. Morgan). pp. 425–450, 1981.

GBPAUT. GBP University of Agriculture and Technology. Integrated natural and human resources planning and management in the hills of UP. Pantnagar, India. Vols. I and II, 1982.

Ghildyal, B.P. Soils of the Garhwal and Kumaon Himalayas. *In:* J.S. Lal (ed.). *The Himalaya: Aspects of Change.* Oxford University Press, Delhi pp. 120–151, 1981.

Gupta, G.P. Sediment production status report on data collection and utilization. *Soil Conserv. Digest* 3 (2): 10–21, 1975.

Gupta, G.P. Soil and water conservation in the catchment of river valley projects. *Status Report Indian J. Soil Conserv.* 8 (1): 1–7, 1980.

ICAR. Indian Council of Agriculture Research. *In:* K.G. Tejwani: *Hand Book of Agriculture: Soil and Water Conservation*, pp. 120–151, 1980.

Jacob, A. Watershed management. New legislation. *Indian J. Soil Conserv.* 9 (2 & 3): 154–163, 1981.

Kaushal, R.C., S.K.N. Dayal and P.R. Mishra. Annual Report Central Soil and Water Research & Training Institute. Dehradun, 1975.

Khybri, M.L., S.N. Prasad and Sewa Ram. Effect of loss of top soil on the yield and economics of maize-wheat rotation. *Indian J. Soil Conserv.* 101: 56–62, 1982.

Kunwar, S.S. Hugging the Himalayas. *Dasholi Gram Swarajya Mandal.* Gopeshwar. pp. 102, 1982.

Mathur, H.N., Rambabu, P. Joshie and B. Singh. Effect of clear felling and reforestation on run off and peak rate of small watersheds. *Indian Forester* 102 (4): 219–226, 1976.

Mathur, H.N., M.C. Agarwal, Rambabu and P. Joshie. Benefit: cost ratio of fuel-cum-fodder plantation in Doon Valley. *Indian J. Soil Conserv.* 7 (2): 53–58, 1979.

Ministry of Agriculture. Statistics on soil conservation, Govt. of India, New Delhi, pp. 74, 1982.

Mishra, P.R., R.C. Kaushal, S.K.N. Dayal and Prabhushankar. Annual Report Central Soil and Water Conservation Research and Training Institute, Dehradun, 1975.

Murthy, B.N. Sedimentation studies in reservoirs. Central Board of Irrigation and Power Technical Report No. 20 Vol. I, New Delhi, 1981.

NCA, Report of National Commission on Agriculture. Govt. of India, New Delhi, 1976.

Planning Commission. Report on development of backward areas. Govt. of India, New Delhi, 1981.

Planning Commission. Report of the task force for the study of eco-development in the Himalayan region: Govt. of India. pp. 152, 1982a.

Planning Commission. Socio-economic development of Himalayan hills. Task force for the study of the eco-development of Himalayan region. Govt. of India, New Delhi, 1982b.

Rambabu, M.C. Agarwal, M.K. Vishwanathan and P. Joshie. Economics and benefit: cost ratio of Eucalyptus plantation for fuel purpose in denuded lands of Doon Valley. National Symposium on Soil Conservation and Water Management in 1980s. Indian Association of Soil and Water Conservationists, Dehradun, 1980.

Seckler, D.W. Economic evaluation of the Fakot Project Report on Operational Research Project (up to Dec. 1978). Central Soil and Water Research and Training Institute, Dehradun, 1979.

Shah, S.L. Agricultural planning and development in the north western Himalayas, India. Nepal's Experience in Hill Agricultural Development. Ministry of Food and Agriculture, HMG, Kathmandu, Nepal, pp. 160–168, 1981a.

Shah, S.L. Presidential address at the 41st All India Agricultural Economics Conference, Dharwar (cited Planning Commission, 1982 a).

Sinha, B. Need of integrated approach to development of catchment and command of irrigation projects. Water International 9 (4): 158–160, 1984a.

Sinha, B. Role of watershed management in water resource development planning. Paper presented at the Workshop on the Management in water resource development planning. Paper presented at the workshop on the Management of River and Reservoir Sedimentation in Asian Countries. East-West Centre, Honolulu (Mimeographed, 1984b).

Swarup, R. and B.K. Sikka. Development of horticulture and conservation of forests in Himachal Pradesh: Need for an integrated approach. *In:* T.S. Papola et al. (eds.) *Development of Hill Areas.* Himalaya Publishing House. Bombay 369–379, 1983.

Tejwani, K.G. Malady—remedy analysis of soil and water conservation in India. *Indian J. Soil. Conserv.* 7 (1): 29–45, 1979a.

Tejwani, K.G. Soil and water conservation: Promise and performance in 1970s. *Indian J. Soil Conserv.* 7 (2) 80–86, 1979b.

Tejwani, K.G. Manpower needs for watershed management in India. Proceedings at the National Seminar on Watershed Management, Forest Research Institute and Colleges, Dehradun. pp. 193–202, 1981.

Tejwani, K.G. Soils policy in India: Need and direction. Transactions of the 12th International Congress of Soil Science, Symposia Papers III: 98–105. New Delhi, 1982.

Tejwani, K.G. Biophysical and socio-economic causes of land degradation and strategy to foster watershed degradation in the Himalayas. IUFRO Symposium on Effects of Forest Land Use on Erosion and Slope Stability. Honolulu, pp. 55–60, 1984a.

Tejwani, K.G. Reservoir sedimentation in India—Its causes, control and future course of action. Water International 9 (4): 150–154, 1984b.

Tejwani, K.G. and Rambabu. Economic evaluation of environmental benefits of soil and water conservation programmes. *Indian J. Soil Conserv.* 10 (283): 80–90, 1982.

UP Government. Hill development at a glance. Hill Division—State Planning Institute, Uttar Pradesh, Lucknow, 1985.

Vimalkishor, B. Singh and G. Sastry. Annual Report, Central Soil and Water Conservation Research and Training Institute, Dehradun, 1980.

Vohra, B.B. Charter for land (Unpublished), 1972.

Vohra, B.B. A charter for land. *Soil Conserv. Digest* 2 (2): 1–25, 1974.

Vohra, B.B. A policy for water. *Soil Conserv. Digest* 3 (1): 1–6, 1975.

14

Cell Biology and Monitoring of Environment

A.K. Sharma

Introduction

The cell biological methods cover both the indication and monitoring of environment. Different techniques have been adopted for decades for an assessment of the environmental status, the hazards to which it is exposed and the extent to which such studies can lead to innovations of remedial measures (Zimmerman and Taylor-Meyer, 1985). Such techniques involve the principle of the relationship between internal levels of exposure and the effects caused thereby. The tests, coming under the orbit of cell biology, principally relate to an understanding of toxicity, mutagenicity and carcinogenicity of the compounds existing in the environment (Levan, 1949; Sharma and Sharma, 1960; Kihlman, 1966; Berg, 1979; Oftedal, 1979; Hollaender and de Serres, 1980; Sharma, 1981; Sugimura et al., 1982; Fishbein, 1984; Sobels, 1984). There test systems can indicate genetic damage, if any, to the system, may be through registering of immediate or distant effect. The radioactive compound too are included, and radiation effects emanating thereby, may have long range consequences. Because the vast array of compounds also mimic radiation effects, the test systems cannot necessarily identify the source of damage. If the source of damage is known then the test systems may be applied for quantification of the damage and prediction of further consequences, thus acting as warning systems.

Cell biological methods, to a great extent differ from the histochemical techniques which actually can identify, in certain cases, the chemical responsible for damage, for example, Rhodamine stain for copper or Prussian Blue method for Iron (Lindquist, 1969). These are some of the histochemical techniques which, if combined with cell biological methods, can lead to the identification of, and the source of damage, on the one hand, and the extent of damage and its consequences on the other.

Test Systems

The tests based on cell biological principles include the classical Ames test, utilizing a series of strains of bacterium, "Salmonella typhimurium". The end result is back mutation in the histidine cistron manifested as bacterial growth on a histidine—less medium. The advantage of this test is its possibility for "direct application" as well as with other mammalian cell extracts for "detoxification". "Salmolella" reversion system has been adopted widely for monitoring affects of drugs, agricultural chemicals, industrial compounds, food additives, drinks, cosmetics, air and water pollutants (Tazima, 1982).

All the cell biological tests are endowed with the advantage of detecting the antagonism and synergism of the different compounds in the environment through the manifestation of their effects on genetic and vis-a-vis chromosomal systems (Giri et al., 1980, 1984; Sharma, 1984). The other genetic tests not necessarily visualizing the effect on chromosome *per se* worked out in "Drosophila" is the detection of dominant lethals. In animals, specially in mouse system, the counts of sears representing dead embryos indicate a clear case of dominant lethality.

In the eukaryotes, a series of tests for identification of chromosome damage ranging from yeast to man have been worked out (Levan, 1949; Kihlman, 1966; Sharma, 1974; Sharma and Sharma, 1980; Hoffman, 1982; Sharma, 1985).

Of the effects on chromosome and the nuclear system, Levan as early as 1949 worked out the "Allium system" and classified the effects under the categories of subnarcotic, narcotic and lethal. The subnarcotics such as phenols, include chromosome breakage, deletions, translocations and other damages which not necessarily lead to lethality, but has the potential of causing genetic changes, if transmitted to the germinal lines. The narcotics on the other hand, involve the effect on the spindle mechanism resulting in disturbance or interference in proper organization leading to polyploidy. The narcotizing agents cover a wide variety of chemicals including colchicine. In both these cases, the effect is "reversible" in the sense that, the tissue can recover once the chemical is removed from the environment though the damage is caused to the genetic system (Levan, 1949). In fact, all such damages have grave consequences on the future of mankind. Most compounds emanating from fertilizer factories, oil refineries and other industries are responsible for the different types of toxicity. The most potent toxic compounds are those which cause immediate cessation of cell division and lethality. Several pesticide residues under certain conditions, such as, methyl isocyanate or phosgene as well as potassium cyanide fall under this category.

The clear liquefaction of nucleic acid has been recorded following cyanide or mercuric chloride treatment.

In plants, like "tradescantia", the change in colour in highly mutagen sensitive staminal hairs has been utilized not merely to monitor low doses of physical and chemical mutagens but air pollutants as well. The mutational events cause a change in colour from blue to pink (Fujii, 1982). Conger (1954) devised an ingenious method employing microspores of "tradescantia" as a "biological dosimeter" to measure the extent of radiation absorbed by the plant while flown through radioactive cloud.

The "Arabidopsis" system with very short life cycle permits an analysis of the events through the entire life span (Fujii, 1982).

In fact, plants have been used for genetic monitoring of environmental mutagens in view of their extreme complexity of genome, comparable to some extent to mammals and their capacity to often activate a promutagen to mutagen. This has been well worked out in maize and other test systems (Plewa, 1982).

The development of "cell and tissue culture techniques" is an effective tool for detecting damage caused by the pollutants in "successive cell cycles" with the associated biochemical events. In addition to plants, the culture technique is valuable for the genetic monitoring of persons exposed to occupational hazards, including air and water pollution.

The "human lymphocyte culture" is a very powerful and a good working system for monitoring mutational effects of environmental pollutants in man *in vivo* (Bochkov, 1982). In view of its reliability, the human peripheral "blood lymphocyte culture" has been advantageously employed as a "hazard indicator". Because of the property of "noninvasiveness" and "long life", such cells can be used as "integrating dosimeters". The accumulation of chromosome damage in man caused by chemicals as well, has been confirmed for a number of industrial compounds such as vinyl chloride, ethylene oxide, ephychlorhydrine as well as heavy metals like chrome and lead (Bochkov, 1982).

The high dosages of strong mutagen often required to demonstrate genotoxicity of mammalian bioassay is a problem to be considered. This is in strong contrast to the low concentration of such compounds encountered in the environment. It is, therefore, extremely important to have a knowledge of differential sensivity of various stages (Sobels and Delehanty, 1982) as well.

The other method is—"Micronuclei test" which in a variety of subjects including "erythrocytes in mouse" is one of the most practical and sensitive *in vivo* test systems (Latt et al., 1982). The presence of micronuclei, which can be detected even at the "interphase" gives a clear indication of the damage to the genetic material. The micronuclei formation can be directly correlated to the extent of damage.

Cytogenetic Parameters for Monitoring

1) One of the important parameters for the estimation of effects is "karyotyping" of the material (Bochkov, 1982) involving comparison of the normal karyotype with the damaged system.

2) Different types of "chromosomal aberrations"—duplication and deletion, including even duplication of the entire complement or polyploidy can be registered in metaphase (Bochkov, 1982).

3) The "fragments and bridges" the two distinct criteria for assessing the damage are best revealed at anaphase (Bochkov, 1982).

4) A very effective cytogenetic parameter of monitoring the damage is the "sister chromatid exchanges (SCE) system", which can be recorded in metaphase and are related to DNA damage and repair (Latt, 1973). They are due to unrepaired lesions present at the S-phase and subsequent chromosome replication (Wolff, 1974, 1977). It can be induced by different chemicals capable of alkylating DNA (Latt et al., 1982). It is more specific than the induction of aberrations. This technique for the localization of SCE is quite simple involving the usual peripheral blood culture as adopted for analysis of chromosomal aberrations, excepting that bromodeoxyuridine is added to the medium for the localization of differentiated chromatid (Wolff, 1977). The SCE can be induced by different agents and different mechanisms are involved for their formation (Wolff, 1978; Carrano et al., 1979).

The potency of this test can be estimated by the fact that it can be caused even by one-hundredth of the exposure required to cause aberrations (Latt, 1973; Perry and Evans, 1975; Solomon and Bobrow, 1975). It has been utilized to assess whether a chemical is potentially dangerous, or to monitor individuals exposed to potentially dangerous compounds in their environment.

Scope of the Tests

Cell biological technique for monitoring and indication of damage principally relate to the genetic system. Over and above, the effects on chromosomes, the different cell organelles, including mitochondria, chloroplastids, nuclear membrane and a host of others often undergo serious damage through environmental pollutants. A study of the structure under light, phase and fluoroscence microscopy as well as ultrastructure through electron microscopy indicates the extent of alterations caused by hazardous compounds. Both genetic damage and cellular damage *per se* can be very precisely ascertained and assessed quantitatively. The limitation however, is the fact that the result of the effects of various types of compounds in the biosphere are often similar. A synthetic approach utilizing histochemical, cytochemical and cell biological techniques is necessary. Such an approach will lead to identification of the source, analysis of the effects and quantification of the damage.

REFERENCES

Berg, K. (ed.) Genetic damage in man caused by environmental agents. Academic Press, New York, 1979.

Bochkov, N.P. The role of cytogenetics in evaluation of human genetic risk. *In:* T. Sugimura, S. Kondo and H. Takebe, (eds.) *Environmental Mutagens and Carcinogens*, University Tokyo Press, Tokyo, Alan R. Liss, Inc. New York, pp. 423-430, 1982.

Carrano, V.V., L.H. Thompson, D.G. Stetles, J.L. Minkler, J.A. Mazrimas and S. Fong. DNA crosslinking, sister chromatid exchange and specific locus mutations. *Mutat. Res.* 63 : 175–188, 1979.

Conger, A.D. Radiobiological studies with *Tradescantia* at nuclear test detonations. *American Naturalist* 88 : 215–224, 1954.

Fishbein, L. Mutagens and carcinogens in the environment. *In*: V.L. Chopra, B.C. Joshi, R.P. Sharma and H.C. Bansal (eds.) *Genetics: New Frontiers*. Oxford IBH Publishing Co., New Delhi, pp. 3–42, 1984.

Fujii, T. Mutagenecity testing of chemical mutagens in higher plants. *In*: T. Sugimura, S. Kondo and H. Takebe, (eds.) *Environmental Mutagens and Carcinogens*, University Tokyo Press, Tokyo, Alan R. Liss, Inc. New York, pp. 399–410, 1982.

Giri, A.K., A. Banerjee, G. Talukdar and A. Sharma. Mutagenic effects of certain common metal toxicants on mammalian system. *Proc. Ind. Acad. Sci.* 89: 311-331, 1980.

Giri, A.K., O.P. Singh, R. Sanyal, A. Sharma and G. Talukdar. Comparative effects of chronic treatment with certain metals on cell division. *Cytologia* 49: 659–665, 1984.

Hoffman, G.R. Mutagenecity testing in environmental toxicology. *Environ. Sci. Technol.* 16: 660A–674A, 1982.

Hollaender, A. and F.J. De Serres, (eds.) Chemical Mutagens: Principles and methods for their detection Plenum, New York, pp. 1–6, 1971–1980.

Kihlmon, B.A. Actions of chemicals on dividing cells. Englewood Cliffs, eds. New Jersey, Prentice Hall, Inc., 1966.

Latt, S.A. Microfluorometric detection of deoxyribonucleic acid replication in human metaphase chromosomes. *Proc. Natl. Acad. Sci.* U.S.A. 70: 3395–3399, 1973.

Latt, S.A., R.R. Schreck, E. Sahar, I.J. Parka and C. Kittrel. Basis of biological significance of sister chromatid exchange. *In*: T. Sagimura, S. Kondo and M. Takebe, (eds.) *Environmental Mutagens and Carcinogens*, University Tokyo Press, Tokyo, Alan R. Liss., Inc. New York, pp. 331–441, 1982.

Levan, A. The influence on chromosomes and mitosis of chemicals as studied by the *Allium* test. Proc. 8th Int. Congr. Genet. Stockholm, Hereditas Suppl. Vol. 325: 337, 1949.

Lindquist, R.R. Studies on the pathogenesis of hepatolenticular degeneration. II cytochemical methods for the localization of copper. *Archives of Pathology*. 87: 370–379, 1969.

Oftedal, P. In Genetic damage in man caused by environmental agents ed. Berg, K., Academic Press, New York, pp. 335, 1979.

Perry, P. and H.J. Evans. Cytological detection of mutagen carcinogen exposure by sister chromatid exchange. *Nature*, 258: 121–125, 1975.

Plewa, M.J. Maize as a monitor for environmental mutagens. *In*: T. Sugimura, S. Kondo and H. Takebe, (eds.) *Environmental Mutagens and Carcinogens*, University Tokyo Press, Tokyo, Alan R. Liss. Inc. New York, pp. 81–90, 1982.

Sharma, A.K. and A. Sharma. Spontaneous and chemically induced chromosome breaks. *Int. Rev. Cytol.* 10: 101–136, 1960.

Sharma, A.K. Plant cytogenetics. *In:* H. Busch, (ed.) *The Cell Nucleus*, 64: 263–291, Academic Press, N.Y., 1974.

Sharma, A.K. and A. Sharma. Chromosome techniques theory and practice, 3rd ed. (A.K. Sharma and A. Sharma) Butterworths, London, 1980.

Sharma, A.K. Impact of the development of science and technology on environment, Presidential Address, 68th Session, ISCA, 1981.

Sharma, A. Environmental chemical mutagenesis in INSA Golden Jubilee Publication, pp. 1–53, 1984.

Sharma, A. Chemical mutagenesis. *In:* A.K. Sharma and A. Sharma (eds.) *Advances in Chromosome and Cell Genetics,* Oxford & IBH Publishing Co., New Delhi, pp. 255–283, 1985.

Sobels, F.H. and J. Delehanty. The first five years of ICPEMC, the International Commission for Protection Against Environmental Mutagens and Carcinogens. *In:* T. Sugimura, S. Kondo and M. Takebe, (eds.) *Environmental Mutagens and Carcinogens,* University Tokyo Press, Tokyo, Alan R. Liss. Inc. New York, pp. 81–90, 1982.

Sobels, F.H. Seven years of the International Commission for Protection Against Environmental Mutagens and Carcinogens (ICPEMC). *In:* V.L. Chopra, B.C. Joshi, R.P. Sharma and H.C. Bansal, (eds.) *Genetics, New Frontiers,* Oxford & IBH Publishing Co., New Delhi, pp. 63-74, 1984.

Solomon, E. and M. Bobrow. Sister chromatid exchange. A sensitive assay of agents damaging human chromosomes. *Mutat. Res.* 30: 273–278, 1975.

Sugimura, T., S. Kondo and H. Takebe. Environmental Mutagens and Carcinogens, ed. University of Tokyo Press, Tokyo, 1982.

Tazima, Y. A brief sketch of environmental mutagen studies in Japan. *In:* T. Sugimura, S. Kondo and H. Takebe, (eds.) *Environmental Mutagens and Carcinogens,* University Tokyo Press, Tokyo, Alan R. Liss. Inc. New York, pp. 91–100, 1982.

Wolff, S. Cytogenetics and environmental mutagens. *In*: V.L. Chopra, B.C. Joshi, R.P. Sharma and H.C. Bansal (eds.) *Genetics: New Frontiers.* Oxford & IBH Publishing Co., New Delhi, Vol. III, pp. 53–62, 1984.

Wolff, S. Sister chromatid exchange. *Ann. Rev. Genet.* 11: 183–201, 1977.

Wolff, S. Chromosomal effects of mutagenic carcinogens and the nature of the lesions leading to sister chromatid exchange. *In:* M.J. Evans and D.C. Cloyd, (eds.) *Mutagen—Induced Chromosome Damage in Man.* Edinburgh University Press, pp. 208–215, 1978.

Zimmerman, F.K. and R.E. Taylor-Meyer. Mutagenicity testing in environmental pollution control. John Wiley & Sons. New York, 1985.

15

Useful Management of Electropollution Caused by Low Level Microwave Radiations in Single Cell Microorganisms

S.K. Dutta, S. Mohammed and I. Sheikh

Introduction and Historical Perspectives

Five years ago, during January 3–7, 1981, I gave a lecture on 'Environmental Impact of Microwave Radiations' at this Congress session, the text of which has been published (Dutta and Gandhi, 1981). This lecture is focused on our recent findings on the useful management of the most prevalent environmental pollutant of mankind, the radiofrequency radiations, which is popularly known as microwave radiations.

An extensive search on historical perspectives and understanding of the nature of electromagnetic radiation are given by Sheikh (1984). The history of microwaves might be said to begin with Faraday in 1832, who described that electromagnetic phenomena were probably the same sort of wave motion as sound or light. Maxwell expressed these concepts mathematically, and in 1846, Hertz demonstrated their physical reality.

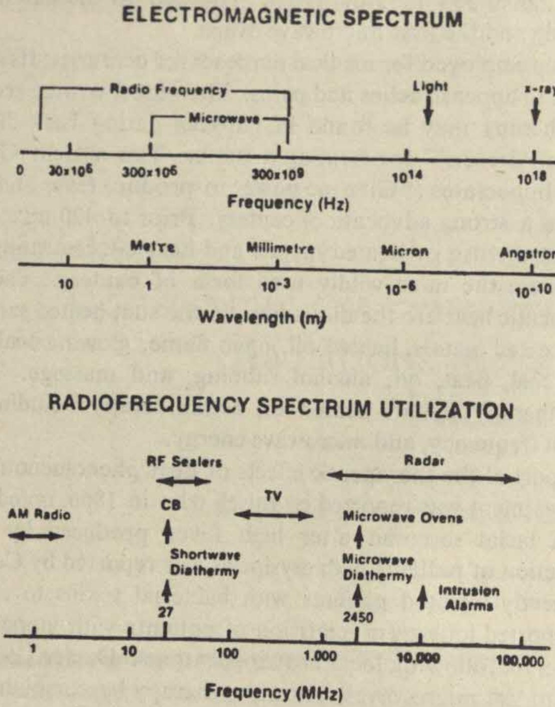
Interest in electromagnetic phenomena increased around the turn of century, and radio communication became its chief first application. In 1904, Christran Hulsmeyer described the principle of radar. The development of radar in World War II stimulated the rapid growth of microwave technology and the development of major vacuum tube sources of electromagnetic energy. The first microwave power application followed soon after. In 1945, Percy Spencer was awarded the first patent on heating food materials with microwaves (issued as a U.S.A. patent on heating food materials with microwaves, Patent 2,605, 383 in July 1952). This led to the development of industrial heating and the first microwave ovens.

Heat has been employed for medical purposes for centuries. Its chief application has been to appease aches and pains. The oldest written record of the use of thermotherapy may be found in Papyrus dating back 3000 B.C. It refers the use of 'fire drill' for treating a tumor. The ancient Greeks used heat therapy. Hippocrates ("Give me power to produce fever and I will cure all disease") was a strong advocate of cautery. Prior to 420 B.C. Aristophanes wrote about the use of heated metals and heat concentrating power of lenses. These were the most wildly used form of cautery. The primitive forms of therapeutic heat are the direct heat of the sun, heated sand, thermal spring water, heated metals, heated oil, open flame, glowing coals, combustion of wood, coal, peat, oil, alcohol rubbing, and massage. The recent forms of heat therapy include heated air, actinotherapy including infrared, shortwave, high frequency, and microwave energy.

The first report of the therapeutic effects of heat phenomenon being useful in cancer treatment was reported by Busch who in 1866, noted the disappearance of a facial sarcoma after high fever produced by erysipelas. Deliberate infection of patients with erysipelas was reported by Coley (1893). Coley subsequently injected patients with bacterial toxins to cause fever. Westermark reported long-term remission of patients with inoperable carcinomas of the cervix following local heat applications. Danier (1936) was the first physician to use microwaves for cancer therapy by combining 80 centimeters P-band microwave and X-rays. Brymer-Ornstein treated an X-ray refractory carcinoma by the use of 60 cm L-band microwave combined with X-rays.

Nature of Microwaves: Microwaves are electromagnetic radiations intermediate in frequency and wavelength between radio waves and far infrared waves. These may be defined as non-ionizing spectrum from 300 MHz to 300 GHz and wavelength between 1000 and 0.06 cm (Fig. 1). At these frequencies, the energy level of one quantum of microwave is approximately 10^{-7} to 10^{-3} electron volts, which is too low to produce ionization of biological molecules as seen following X-ray and gamma radiation. The radio frequency radiation of most interest includes those frequencies whose wavelengths are comparable to the size of the human body or of parts of the body. Some of the common devices that emit relatively significant level of radio frequency and microwave radiation are frequencies used in television signal relay radar, long distance telephony, microwave ovens and electrotherapy. Frequencies of interest with respect to biological hazards are those lying between 10 MHz and 10 GHz where the wavelength ranges from 96 feet (30 m) to 1.2 inches (3 cm). Possible hazards at frequencies less than 100 MHz are still under investigations.

Microwave radiation may be either the continuous wave type used in



ELECTROMAGNETIC SPECTRUM

RADIOFREQUENCY SPECTRUM UTILIZATION

Fig. 1. Frequency spectrum of microwaves.

communication systems or the pulse type used for radar installations, industrial, and medical equipments. Microwave radiation may be reflected, transmitted, absorbed or any combination of these depending on the nature of the material interposed in the path of radiation. It is complicated to determine the portion of incident energy that is absorbed if the target is a human being. This is due to the inhomogeneity of the target, differences in sensitivity of organs and tissues, body mass in relation to the exposed area, and the frequency of the microwaves. The electric and magnetic field strengths generally fall off as distance from the source increases.

Safety Standards: It was the major concern of both military and civilian authorities to establish safe limits of exposure for personnel engaged in the development and operation of microwave equipments. Schwan and Li (1956) recommended a tolerance dose of 10 mW/sq cm. Review of all the experimental data on animals at that time revealed that an exposure to a power density of approximately 0.1 mW/sq cm was necessary to produce any biological effect. The radio frequency and microwave radiation safety standard that have prevailed from 1974 to the present in the U.S.A. are given in Table 1. In most of the U.S.A. safety standards, a 6 minute averaging time is specified, which accounts for the action of human body and its ability to dissipate various level of internal heat created by radio frequency and microwave radiation. The American National Standard Institute (ANSI) has reduced the permissible exposure level in the 30 to 300 MHz region. In the U.S.S.R. and some East European Countries, the standard for an occupational exposure per day is 0.01 mW/sq cm.

Mode of Action of E.M.R. on Biological Tissues: The mechanism responsible for interaction of microwave with biological materials and the heat development caused by electromagnetic energy per unit volume of tissue is given as:

$$P=1/2\,\sigma\,E^2$$

Where E^2 = Electric field intensity
σ = Conductivity
Conductivity can be expressed as a sum of various components:

$$\sigma=\sigma_I+\sigma_W+\sigma_B+\sigma_{BW}+\sigma_L$$

In this equation, the subscripts indicate:

I = Ions
W = Water
B = Biopolymers
BW = Bound Water
L = Lipid

Ionic conductivity σ_I is frequency independent and over the entire microwave frequency region has an approximate value of 10 mS/cm for soft tissues. It is also well known that σ_R and σ_L has minimal contribution. Dominant frequency-dependent component of electrical conductivity are free and bound water. Grant (1980) demonstrated that specific absorption due to bound water is significantly larger than that of free water between the frequency of 0.1 and 1.0 GHz. This finding is important in cancer therapy, since the water content of malignant and normal cells may be different.

Microwaves can also couple energy into biological tissues through membrane interaction. The majority of classical interactions between electromagnetic waves and membranes occur at frequencies well below the microwave region. The threshold for initiating such interactions is much higher than the field intensity used in clinical hyperthermia.

There has been a great deal of controversy over the potential health hazards of low level electromagnetic radiation. Biological organisms behave like ordered systems with apparently some spatial ordering and can transform energy not only into heat but also into conformation. A cell membrane is the primary site of thermal microwave interaction. It is characterized by a high polarization field on the order of 10^7 v/m. Frohlich (1978) has proposed a model assuming that metabolic energy is fed into dipolar modes of longitudinal oscillation into the regions of biological membranes or parts of a giant molecule. According to his calculations, the energy is channeled strongly into the lowest polar mode, thus causing a coherent oscillation.

The metabolic process can pump energy into dipoles modes of sections of giant molecules such as DNA. Frohlich (1978) estimated the frequencies for such modes ranging from 10 GHz to thousands of GHz. Frohlich speculated that microwaves could be absorbed by the biological systems via excitation of some modes. Energy will in turn be channeled into the dominant mode to trigger biological actions. Webb and Stoneham (1977) have confirmed the existence of long-range coherent vibrations of the conjectured type by laser Raman spectroscopy at frequencies ranging from 50 to 100 GHz in active bacterial cells. Grundler et al. (1977) reported similar observations in yeast and bacterial systems. Webb and Stoneham (1977) have demonstrated the existence of several such modes in the 50 to 100 GHz range in the mammary tissues, and claimed a significant splitting of the mode lines in the case of cancerous tissues. Prohofsky (1978) discovered structural modes that pull bases apart, and acoustic modes which represent uniform translations and twists at roughly 10 GHz range. These modes can drive a conformational change of DNA from B to A conformation. Thus, microwaves could affect biological processes through harmonic coupling with these modes.

Genetic and Cellular Damage: The exact nature of the biologic effects of microwave radiation is not completely understood. The most investigated and documented effect of radio frequency on biological tissues is the transformation of electromagnetic energy into kinetic energy of the absorbing molecules, thereby producing a general heating in the medium. The heating results from ionic conduction and vibration of the dipole molecules of water and proteins. The power absorbed by the tissues will produce a temperature rise that is dependent on the cooling mechanisms of the tissue. The polar molecules tend to line up and vibrate in an applied electrical field. In turn microwave radiation causes the field to oscillate which results in the oscillation of molecules with greater altitude than normal thermal vibrations.

Herrick and Krusen (1953) pointed out that heat generation and microwave absorption is greater in those tissues with high water content such muscle brain tissue, internal organs, and skin. It is enhanced locally in the areas adjacent to bone or tough facial planes which act as reflecting surfaces (Schwan and Li, 1956). Several investigations have pointed out the possibility of microwave interaction with biological systems without an increase in temperature of the specimen. Herrick and Krusen (1953) also observed that the non-thermal effect is due to forces acting on particles and called it 'the pearl effect'. This effect is seen when suspended particles of charcoal, milk, starch erythrocytes, or leucocytes are placed in a continuous or pulsed radio frequency field in the range of one to 100 MHz. Furedi and Valentine (1962) quantified chain formation and reported that it was due to the attraction between particles in which dipole charges are induced by the radio frequency field. Another non-thermal effect is the dielectric saturation occurring in solutions of proteins and other biological macro-molecules due to microwave fields. Schwan and Li (1956) suggested that macro-molecules can line up with the direction of the electric field due to the production of polarized side chains by microwave fields. This would lead to a possible breakage of hydrogen bonds. Fleming (1961) reported that such effects can cause denaturation or coagulation of molecules.

The degree of temperature rise from exposure to microwave is dependent on numerous physical and biological factors:

1) Intensity or power density: the amount of heat produced is proportional to the power density as measured in mW/sq cm.
2) Duration of exposure.
3) Frequency or wavelength of the radiation.
4) Size and dimension of the exposed object.
5) Thermal regulatory capacity of the exposed subject.
6) Thickness of tissue.
7) Composition of tissue.

The biological factors in temperature rise are mainly those related to the ability of the tissue to get ride of excess heat. If the organism can not dissipate heat as it is produced, the internal temperature of body will rise. The body's ability to dissipate heat depends upon many factors such as environmental air circulation rate, humidity, air temperature, body metabolic rate, clothing, power density of the radiation field, amount of energy absorbed, and duration of exposure. If the exposure is not prolonged and the areas have adequate blood circulation, the measured oral and rectal temperatures may remain normal. Presently available information indicate that eyes and testes are the most vulnerable to microwave radiation due to lack of an adequate vascular system for the exchange of heat.

Radiation at frequencies below 1000 MHz causes heat to be developed in the deep tissues. Frequencies greater than 3000 MHz cause heating of tissues in the same manner as does infrared radiation or direct sunlight. Radiation at frequencies between 1000 and 3000 MHz results in varying degrees of penetration depending upon the thickness of the tissues, dielectric constant, conductivity, and the frequency of radiation.

The widespread use of microwave generators for military, radio and television stations, tracking communication, and other industrial purposes pose a potential hazard to the health of personnel concerned with their operation. The potential hazards of these devices were recognized early in their development during the early days of World War II, when studies were conducted on the U.S. Navy personnel engaged in the operation and testing of low powered radar (Dailey, 1943).

Studies done on experimental animals indicate that cataracts, corneal opacities, testicular degeneration and hemorrhage could be produced by microwave exposure (Dailey, 1943).

Cataracts were reported in rabbits after a single exposure to 2450 MHz continuous wave for 270 minutes at a dose rate of 120mW/sq cm and at dose rate of 600 mW/sq cm after five minutes. Cataracts were first observed in a technician operating a radar unit in the 1500 to 3000 MHz range, with exposure to 100 mW/sq cm for a one year period. Singler et al. (1965) reported an increased incidence of Down Syndrome in children of fathers having prior exposure to radar. Since that time several efforts have been made to better organize, consolidate, and disseminate international literature on the general subject of the biological effects of microwaves.

Soviet studies of occupational workers exposed to microwave power densities generally well below 10 mW/sq cm continue to report various reversible changes in central nervous systems, cardiovascular, and blood systems which lead to a characteristic complex of clinical symptoms. Several investigators have reported various degrees of damage to testes due to microwave exposure such as edema, enlargement of testes, atrophy, fibrosis and coagulation necrosis of seminiferous tubules in animals exposed to 2450, 3000 and 10,000 MHz at power densities of about 10 to 15 mW/sq cm (Ely et al., 1957). They reported 10 mW/sq cm to be the 'Threshold' for testicular damage from an indefinite exposure using 2880 MHz. A general decrease in sex function and spermatogenesis have been reported by Lancranjan (1975).

Lobanova (1974) reported behavioural changes in response to low intensity microwave at a dose rate of 0.5 to 10 mW/sq cm. These changes were accompanied by depressed brain cholinestrase activity, and reversible lesions of cortical neurons, synapses and neurologia. Some scientists believe that microwaves at low power densities can act psychophysiologically. One investigator believes that certain modulated radio frequency or microwave fields at a power density of 1 mW/sq cm can be used to directly programme verbal information into the brain via extra auditory and extra visual pathways. Schapitz (1975) designed an elaborate experiment to support this hypothesis. So far, there is little evidence to suggest that such a phenomenon is possible, with the possible exception of 'microwave hearing' at low power densities. Changes in the blood protein chemistry and the hematopoietic system of occupational workers reported in Soviet and East European clinical studies.

Efflux of potassium and hemoglobin from erthrocytes exposed at 1.0 mW/sq cm have been reported.

Heller and Teixeira (1959) have reported chromosomal breaks in garlic root tips exposed at 27 MHz for five minutes. They have shown that there was no change in optical density and viscosity of bacterial DNA between 10 Hz and 100 KHz, but an increased stickiness of chromosomes in Chinese hamsters exposed at 2.45 GHz. Szmigrelski et al. (1975) observed increased replication of viruses irradiated at 5 mW/sq cm, while decreased replication was noted at 20 mW/sq cm. A western study of cell metabolism found a marked increase in protein synthesis in liver, thymus and spleen at 2 mW/sq cm after 160 hours.

Blackman et al. (1975) have shown that 1.7 and 2.45 GHz microwave radiation did not cause mutation in a bacterial system. Lack of genetic effects of microwave radiation are reported by Dutta et al. (1979). Dutta et al. (1984) have shown microwave induced calcium efflux from human neuroblastoma cells exposed to 915 MHz at a dose rate of 0.05 and 1.0 mW/sq cm using amplitude modulation at 16 Hz.

Medical Applications of Microwaves: Microwave power densities up to 590 mW/sq cm are being used in clinics for routine diathermy treatment in many locations of the human body (Schwan and Li, 1956). Cancer cells are more sensitive to hyperthermia than normal cells from homologous tissue. An increase of temperature above 41°C provides a promising method for the selective killing of cancer cells. Radio frequency heating at a frequency of 14, 434, and 915 MHz has been used for tumor eradication (LeVeen and Waprick, 1976).

The frequencies of 27, 41, 433, 915, 2,450, and 5,800 MHz are significant since they are used for industrial, scientific, and medical heating processes. The frequencies of 27, 915, and 2,450 MHz are used for diathermy purposes in the U.S.A., whereas only 433 MHz is authorized in Europe for these purposes.

Following in the work of Third Industrial Revolution, centered around high technology, the field of what has come to be called 'Electropollution' has become not merely a new field for scientists to cultivate—it has also become one of considerable social concern, for extending the bounds of environmental protection. The social concern stems from its pervasive, invisible nature, hence of the difficulty of social regulation and/or action for necessary amelioration.

During the last 30 years, numerous workers around the world, as has been reviewed recently by Cleary (1986), have studied the biological effects of these electropollutants but there is still significant uncertainty about many aspects of their findings. The most significant reason for this uncertainty being the physiological complexity of mammals and their spatially complex physical bodies. The studies of the effects of non-ionizing electromagnetic radiation on cells *in vitro* are beginning to provide answers to these questions. The extremely low level microwave radiation induced cellular effects, such as $^{45}Ca^{++}$ efflux enhancements in human brain cells as shown by us (Dutta et al., 1984), clearly demonstrate the usefulness of cellular systems over complex mammalian systems for understanding basic mechanisms of such EMR effects.

During 1983, two significant studies were published (Raji and Bowden, 1983; Goodman et al., 1983) which motivated us to embark on the studies which are being presented here. Raji and Bowden (1983) have shown that pulsed EMR (electromagnetic radiations) accelerated the recovery of injured limbs and regeneration of common peroneal nerves in rats. Goodman et al. (1983) have shown furthermore that pulsed EMR increased the specific activity of messenger RNA after 15 minutes of exposure. We have extended these studies in cellular systems, like the bacteria, *Escherichia coli*, the yeast *Saccharomyces cerevisiae*. Results presented here confirm the beneficial effects of low intensity EMR in recovering regeneration of cellular and RNA molecules, thereby recovering heat damages to these cells by heat induced by high intensity EMR or by exposure to conventional heating.

Methods and Materials

Culturing and maintenance of genetically well known haploid stains of the bacterium *Escherichia coli* and the yeast *Saccharomyces cerevisiae*, preparation of cultures for microwave radiations, dosimetry and instrumentations (Crawford Exposure Systems) are as have been described in a monograph published by the U.S. Environmental Protection Agency (Dutta, 1980; Dutta and Gandhi, 1981).

The general design of the experimental scheme is described through Fig. 2, which is self-explanatory. Thermal damage of *E. coli*, and yeast cells was produced by heating the cells at 49°C ± 2°C, and 46°C respectively for 90 minutes. The microwave damage of the cells was caused by exposing the cell culture to high intensity radiation of 915 MHz, CW at SAR (power level described as specific absorption rates) 315 mW/g for 3 hours. Radio frequency exposure system and dosimetry are described by Dutta et al. (1984). *E. coli* (strain W3110) and *S. cerevisiae* (S288C) were chosen because of the intensive work already done on these organisms for genetic and physiological studies. These are all normal cultures and are easily obtainable for American Type

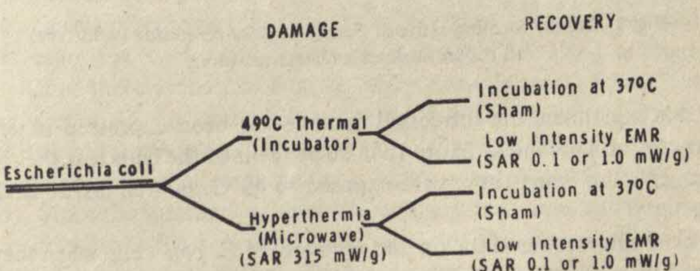

DAMAGE
RECOVERY
Escherichia coli
49°C Thermal (Incubator)
Hyperthermia (Microwave) (SAR 315 mW/g)
Incubation at 37°C (Sham)
Low Intensity EMR (SAR 0.1 or 1.0 mW/g)
Incubation at 37°C (Sham)
Low Intensity EMR (SAR 0.1 or 1.0 mW/g)

Fig. 2. Experimental design for studying thermal damage.

Culture Collection, MD, Food and Drug Administration, Genetic Toxicology Branch, Washington, D.C. and from the Fungal Genetics Stock Center, Kansas City, MO.

Enhanced cellular regeneration was studied with single cell organisms *E. coli* and *Saccharomyces cerevisiae*. Damaged cells were exposed to low intensity microwave radiation at dose rates of 0.1 and 1 mW/g. For studies on molecular regeneration of RNA molecules, spheroplasts were prepared from damaged yeast cells and were ^{3}H-labeled with 1 uCi/ml ^{3}H-Uridine. RNA extraction of irradiated and non-irradiated cells and electrophoresis on agarose gel was performed according to the methods of Maniatis et al. (1982).

Results

Significant decreases in colony-forming units of normal *E. coli*, and *Saccharomyces cerevisiae* cells occur when temperature increases. Figure 3 shows typical data on the growth pattern of yeast cells at various time and temperature. As shown in Fig. 3 yeast cells were damaged more than 90 per cent (i.e. loss of ability to form colonies on agar plates) at 46°C whereas it took 49°C to cause 90 per cent damage in *E. coli* cells. According to our estimates radio frequency radiation at SAR 315 mW/g also generated 49°C temperature as well as 90 per cent damage to *E. coli* cells.

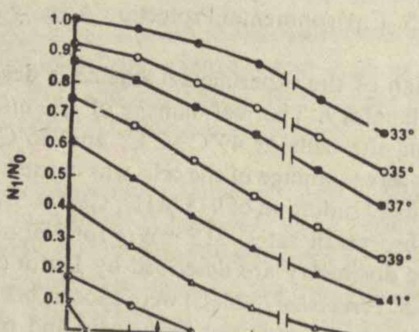


Fig. 3. Colony forming units of *Saccharomyces cerevisiae* (wild type) at different times and temperatures.

In this experiment the sub-lethal damage has been expressed in terms of inability to form colonies. More than 90 per cent of the cells lost their ability to form colonies when they were exposed to 49°C as well as at SAR 315 mW/g.

Table 2 summarizes data on the recovery of *E. coli* cells when they were damaged by conventional heating at 49°C for 90 minutes. The damaged cells in suspension were then exposed to low intensity microwave radiation at dose rates of 0.1 or 1 mW/g and showed a consistent increase in their recovery rates.

TABLE 2

Summary of cell recovery of *E. coli* cells exposed to low level microwave radiation and 37°C incubation after thermal damage at 49°C for 90 minutes

Time of exposure (hours)	Damaged cells			
	SAR 0.1 mW/g		SAR 1.0 mW/g	
	N_s/N_o ave. ± S.D.	N_r/N_o ave. ± S.D.	N_s/N_o ave. ± S.D.	N_r/N_o ave. ± S.D.
1	0.115 ± .009	0.164 ± .081	0.070 ± .006	0.110 ± .019
3	0.310 ± .022	0.426 ± .032	0.142 ± .050	0.162 ± .023
5	1.63 ± .184	1.81 ± .135	1.55 ± .036	1.72 ± .186
7	4.34 ± .308	4.59 ± .311	4.37 ± .036	4.38 ± .221
10	6.81 ± .381	7.24 ± .227	6.77 ± .010	7.11 ± .378

N_o = Initial number of colony forming units before damaging the cells (approx. 160×10^6 colonies typically), diluted 10^6 by 0.9 per cent saline/plate.

N_s = Number of colony forming units obtained after incubation of damaged cells in Crawford cell at 37°C but not exposed to low intensity microwave radiation (sham).

N_r = Number of colony forming units obtained after low intensity microwave radiation treatment of damaged cells in Crawford cell at 37°C.

S.D. Standard Deviation.

Table 3 shows data on recovery of *E. coli* cells damaged by high intensity EMR at a dose rate of 315 mW/g for 3 hours, and subsequent exposure to low intensity microwave radiation at a dose of 0.1 or 1 mW/g. The recovery (N_r/N_o) of *E. coli* cells showed a consistent increase in the recovery rate. The enhancement of recovery was determined by comparing the levels of recovery obtained from low intensity microwave and the corresponding sham treatments of the damaged cells.

These levels of recovery (Tables 2 and 3) were compared by statistical analysis using the two-way analysis of variance (ANOVA) of fixed effect model. All of these statistical analyses were done by using SAS (Statistical Analysis System)-76 computer programming. F-Statistics at both power levels (SAR 1.0 and 0.1 mW/g) indicated that the difference between low intensity EMR treated and the corresponding sham was found to be significant ($P < .05$). Since the interaction between recovery and time was significant, it was concluded that the recovery levels were not the same in all cases. The interaction between dose rate (mW/g) and time of exposure was also tested and was found to be significant ($P < .05$).

TABLE 3

Summary of cell recovery of *E. coli* cells exposed to low level microwave radiation and 37°C incubation after thermal damage caused by high intensity (Hyperthermia) microwave radiation at SAR 315 mW/g

	Damaged cells			
Time of exposure (hours)	SAR 0.1 mW/g		SAR 1.0 mW/g	
	N_s/N_o ave. ± S.D.	N_r/N_o ave. ± S.D.	N_s/N_o ave. ± S.D.	N_r/N_o ave. ± S.D.
1	0.231 ± .015	0.256 ± .093	0.204 ± .024	0.222 ± .052
3	1.02 ± .118	1.19 ± .111	0.998 ± .052	1.14 ± .155
5	2.00 ± .005	2.37 ± .171	1.92 ± .132	2.16 ± .214
7	3.52 ± .188	3.84 ± .277	3.66 ± .055	4.00 ± .283
10	6.21 ± .266	6.97 ± .277	6.57 ± .229	7.02 ± .017

N_o = Initial number of colony forming units before damaging the cells (approx. 160×10^6 colonies typically), diluted 10^6 by 0.9 per cent saline/plate.

N_s = Number of colony forming units obtained after incubation of damaged cells in Crawford cell at 37°C but not exposed to low intensity microwave radiation (sham).

N_r = Number of colony forming units obtained after low intensity microwave radiation treatment of damaged cells in Crawford cell at 37°C.

S.D. Standard Deviation.

RECOVERY OF DAMAGED YEAST CELLS AT CELLULAR LEVEL

Conventional heating and high intensity EMR was used to produce a sublethal heat damage. Control (N_o), sham (N_s), and irradiated cells (N_r) were taken from the same cell suspension for each experiment. Heat damaged cells in suspension were exposed to low intensity EMR at a dose rate of .1 mW/g and 1 mW/g at 915 MHz. Both strains show a consistent increase in the recovery rate. Recovery has been described as N/N_o, where N is the recovered number of colony forming units/ml at any specified time and N_o is the initial number of colony forming units at time 'zero'. Tables 4 and 4A summarize the cell recovery of wild type exposed at .1 mW/g after thermal damage by conventional heating at 46°C for 60 minutes. Table 4A shows the statistical comparison of both sham and irradiated cell recovery at .1 mW/g by two way analysis of variance. At .1 mW/g, the recovery of wild type was found to be 95 per cent after 7 hours and 91 per cent after 10 hours. Fs of irradiated vs sham is 8.5444* and Fs of time of incubation is 501.9195**. There was a significantly higher number of cells recovered due to radiation treatment as compared with sham ($P < .05$). There was a significant increase in the number of cells recovered from both the sham and irradiated after approximately 7 hours of incubation ($P < .01$).

* ($P < 0.05$)
** ($P < 0.01$)

TABLE 4

Summary of cell recovery of *Saccharomyces cerevisiae* (wild type) exposed to low microwave radiation at a dose rate of 0.1 mW/g after thermal damage at 46°C for 60 minutes

Time of exposure (hours)	Undamaged cells N_l/N_o ave. ± S.D.	Damaged cells N_s/N_o ave. ± S.D.	N_r/N_o ave. ± S.D.
1	1.0 ±0.06	0.11±0.02	0.13±0.02
3	1.36±0.06	0.29±0.04	0.34±0.04
5	2.33±0.12	1.36±0.06	1.58±0.12
7	4.23±0.15	3.58±0.06	4.02±0.09
10	6.89±0.09	5.61±0.12	6.29±0.09
15	8.12±0.24	6.45±0.24	6.86±0.18

N_o = Initial number of colony forming units before damaging the cells (approx. 170×10^5 colonies typically), diluted 10^5 by 0.9 per cent saline.

N_l = Number of colony forming units obtained from normal growth of undamaged cell incubated at 30°C.

N_s = Number of colony forming units obtained after incubation in Crawford cell but not exposed to low intensity microwave radiation (Sham).

N_r = Number of colony forming units obtained after low intensity microwave radiation treatment in Crawford cell at 30°C.

S.D. Standard Deviation.

TABLE 4A

Statistical comparison of sham and irradiated cell recovery at *Saccharomyces cerevisiae* (Wild Type) at 0.1 mW/g by analysis of variance

Source of variation	SS	df	MS	F_s
Irradiated vs Sham	0.2760	1	0.2760	8.5444*
Time of incubation	81.0601	5	16.2120	501.9195**
Error S.S.	0.1616	5	0.0323	n.s.
Total	81.4977			

Correlation coefficient between sham and irradiated cells of *Saccharomyces cerevisiae* is 0.9999.**

*($P < 0.05$)
**($P < 0.01$)

The correlation between sham and irradiated was .9999. This suggests that as the length of incubation time increases, there is an increase in the number of cells recovered in both the sham and irradiated. However, the number of cells recovered after irradiation is significantly higher than the sham. Figure 4 shows the best fit regression curve of sham and irradiated cell recovery of wild type at .1 mW/g after heat damage.

Similar cell recovery of wild type was obtained at 1 mW/g after thermal damage at 46°C for 60 minutes. At 1 mW/g the recovery of wild type was found to be 93 per cent after 7 hours and 84 per cent after 10 hours. Statisti-

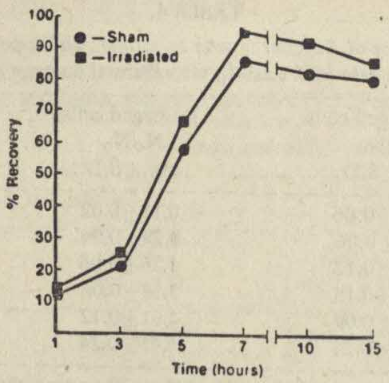


Fig. 4. Cell recovery of *Saccharomyces cerevisiae* (wild type) at 0.1 mW/g after thermal damage at 46°C.

cal comparison of sham and irradiated cell recovery of wild type at 1 mW/g Fs of irradiated versus sham is 10.7488* and Fs of time of incubation is 501.9195**.

There was a significantly higher number of cells recovered due to radiation treatment as compared to sham ($P < .05$). There was a significant increase in the number of cells recovered from both the sham and irradiated after approximately 7 hours of incubation ($P < .01$).

The correlation between sham and irradiated was 0.9993. This suggests that as the length of incubation time increases, there is an increase in the number of cells recovered in both the sham and irradiated. However, the number of cells recovered after irradiation is significantly higher than the sham. Tables 5 and 5A summarize the cell recovery of wild type at .1 mW/g after thermal damage at 340 mW/g (46°C) for 3 hours. At 0.1 mW/g, the recovery of wild type was found to be 93 per cent after 7 hours and 87 per cent after 10 hours. Table 5A shows the statistical analysis of sham and irradiated cell recovery of wild type at 0.1 mW/g. Fs of irradiated versus sham is 10.5454* and Fs of time of incubation is 654.1281*.

There was a significantly higher number of cells recovered after radiation treatment as compared to sham ($P < 0.05$). There was a significant increase in the number of cells recovered from both the sham and irradiated after approximately 7 hours of incubation ($P < 0.01$).

The correlation between sham and irradiated was 0.9996. This suggest that as the length of incubation time increases there is an increase in the number of cells recovered in both the sham and irradiated. However, the number of cells recovered after irradiation is significantly higher than the sham.

Figure 5 shows the best fit regression curve of sham and irradiated cell recovery of wild type at .1 mW/g after heat damage by high intensity electromagnetic radiation at 340 mW/g (46°C).

TABLE 5

Summary of cell recovery of *Saccharomyces cerevisiae* (Wild Type) exposed to a dose rate of 340 mW/g microwave radiation and recovered at low level microwave radiation at a dose rate of 0.1 mW/g at 30°C

Time of exposure (hours)	Undamaged cells N_1/N_o ave. ± S.D.	Damaged cells N_s/N_o ave. ± S.D.	N_r/N_o ave. ± S.D.
1	1.0 ± 0.6	0.10 ± 0.02	0.12 ± 0.02
3	1.36 ± 0.06	0.27 ± 0.04	0.35 ± 0.02
5	2.33 ± 0.12	1.39 ± 0.03	1.62 ± 0.05
7	4.23 ± 0.15	3.54 ± 0.08	3.94 ± 0.07
10	6.89 ± 0.09	5.56 ± 0.06	5.99 ± 0.12
15	8.12 ± 0.24	6.38 ± 0.12	6.97 ± 0.13

N_o = Initial number of colony forming units before damaging the cells (approx. 170×10^5 colonies typically), diluted 10^5 by 0.9 per cent saline.

N_1 = Number of colony forming units obtained from normal growth of undamaged cell incubated at 30°C.

N_s = Number of colony forming units obtained after incubation in Crawford cell but not exposed to low intensity microwave radiation (Sham).

N_r = Number of colony forming units obtained after low intensity microwave radiation treatment in Crawford cell at 30°C.

S.D. = Standard Deviation.

TABLE 5A

Statistical comparison of sham and irradiated cell recovery of *Saccharomyces cerevisiae* (Wild Type) at 0.1 mW/g after thermal damage at 340 mW/g by analysis of variance

Source of variation	SS	df	MS	Fs
Irradiated versus sham	0.2552	1	0.2552	10.5454*
Time of incubation	79.1497	5	15.8299	654.1281**
Error S.S.	0.1211	5	0.0242	
Total	79.5260			

Correlation coefficient between sham and irradiated cells of *Saccharomyces cerevisiae* is 0.9996.*

* $(P < 0.05)$

** $(P < 0.01)$

Table 6 summarizes recovery studies in yeast as percentages for easy reference.

RNA RECOVERY STUDIES IN YEAST CELLS

Table 7 shows data on microwave induced RNA regeneration of heat damaged cells of wild type at 1.0 mW/g, the recovery of RNA resynthesis was

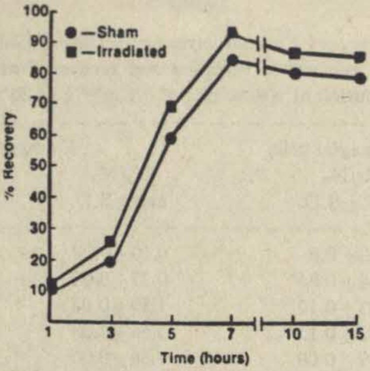


Fig. 5. Cell recovery of *Saccharomyces cerevisiae* (wild type) at 0.1 mW/g after thermal damage at 340 mW/g.

TABLE 6

Summary of percentage recovery of *Saccharomyces cerevisiae* (Wild Type) exposed to low level radiation after thermal damage at 46°C for 60 minutes

Time of exposure (hours)	Percentage recovery SAR 0.1 mW/g		Percentage recovery SAR 1.0 mW/g	
	N_s/N_o	N_r/N_o	N_s/N_o	N_r/N_o
1	11	13	9	12
3	21	25	19	22
5	58	68	52	62
7	85	95	82	93
10	81	91	77	84
15	79	84	75	80

Percentage recovery was calculated using the formula.

$$\frac{N_s/N_o}{N_I/N_o} \times 100 \text{ or } \frac{N_r/N_o}{N_I/N_o} \times 100$$

93 per cent after 7 hours and 68 per cent after 10 hours as compared to sham which shows 77 per cent and 62 per cent recovery at the same time intervals.

Table 7A shows the statistical comparison of RNA regeneration by microwave induced cell recovery of wild type at 1.0 mW/g by two way analysis of variance. Fs of irradiated versus sham is 10.0625* and Fs of time of incubation is 90.1875**.

There was a significantly high concentration of RNA regenerated after radiation treatment as compared to sham ($P < 0.05$). There was a significant increase in the concentration of RNA resynthesized from both the sham and irradiated after approximately 7 hours of incubation ($P < 0.01$).

TABLE 7

Summary of calculated data in ^{3}H-labels as counts per minute (cpm) on RNA regeneration by microwave induced recovery of *Saccharomyces cerevisiae* (Wild Type) cells at 1.0 mW/g following thermal damage at 46°C

Time of exposure (hours)	Undamaged cells N_I ave. CPM	Damaged cells			
		N_s/N_I ave.—S.D.	% recovery	N_r/N_I ave.—S.D.	% recovery
1	1923	.13±.03	13	.14±.05	14
3	3875	.24±.04	24	.27±.03	27
5	7254	.56±.06	56	.68±.04	68
7	12445	.77±.07	77	.93+.06	93
10	18674	.62+.05	62	.68+.05	68
15	26773	.57+.07	57	.63+.03	63

Heat damage was done at 46°C for 60 minutes. Heat damaged cells were converted to spheroplasts. Spheroplasts ware labelled using 1 μCi/ml of tritiated uridine. Five ml of cell suspensions in two tissue culture flasks were exposed to low intensity EMR at a dose rate of 1 mW/g for 1, 3, 5, 7, 10 and 15 hours. After exposure, the pulse was terminated by the addition of ice-cold ethanol. Cells were harvested by centrifugation and washed 8–10 times till the background count was between 40 and 50 CPM. After the final wash, the radioactivity of the precipitated pellet was determined.

N =Tritiated uridine incorporation into undamaged cells at 30°C.

N_s=Tritiated uridine incorporation into heat damaged cells kept in Crawford cell without EMR at 30°C.

N_r=Tritiated uridine incorporation into heat damaged cells exposed to low intensity EMR at a dose rate of 1 mW/g at 30°C.

TABLE 7A

Statistical comparison on RNA regeneration by microwave induced cell recovery *Saccharomyces cerevisiae* (Wild Type) at 1.0 mW/g by analysis of variance

Source of variation	SS	df	MS	Fs
Irradiated vs. sham	0.0161	1	0.0161	10.0625*
Time of incubation	0.7213	5	0.1443	90.1875**
Error S.S.	0.0079	5	0.0016	n.s.
Total	0.7453			

Correlation coefficient between sham and irradiated cells of *Saccharomyces cerevisiae* is 0.9948**.

* ($P<0.05$); ** ($P<0.01$)

The correlation between sham and irradiated was 0.9948. This suggest there is an increase in the concentration of RNA regenerated on both the sham and irradiated. However, the concentration of RNA regenerated after irradiation is significantly higher than the sham.

Discussion

The negative aspects of biological effects of low power level Electropollution (caused by EMR) particularly in causing brain tumors in changing human and animal behaviours and causing imbalance in $^{45}Ca^{++}$ effluxes and in several other neurochemical effects are well established. These data were recently discussed in a symposium and are being published as a book (Dutta and Millis, 1986). Fortunately this menace of electropollution occur at unique combinations of power and frequency levels. If those specific combinations of electropollution are avoided, the same electromagnetic radiation (EMR) can also be managed for various useful purposes for mankind.

In this lecture I have summarized useful uses of electromagnetic radiations. Numerous data and figures presented showed significant enhanced recovery of damaged *E. coli* and yeast cells by low intensity CW microwave radiation at 915 MHz. The damages caused by both conventional heating and high intensity microwave radiation were found to be inversely exponential. The inability to form colonies is defined as 'damage' here. The recovery involves cell to cell contact or can also be a function of environmental conditions and cell line.

It has been well demonstrated that during thermal injury there is marked degradation of ribosomes and that resynthesis occurs during recovery process. The results presented indicated significant higher recovery of high molecular weight RNA (ribosomal RNAs) in irradiated cells than in sham (i.e. control) experiments.

These findings at the cellular (Clark et al., 1968) and at the molecular level (Goodman et al., 1983) were also observed by others. Results presented did provide conclusive evidence that low level microwave radiation can be used in recovering heat damaged cells. Therapeutic application of this knowledge can increase the probability of the regeneration of damaged tissues by using low level microwave radiation.

All experiments were conducted at least three times to check consistency of data. For accuracy of the results the initial undamaged cell concentration N_o, measured in terms of colony forming units (CFU) was kept between 1.5×10^8 and 2.0×10^8 CFU/ml. Various time intervals were used to quantify the number of cells which recovered after sustaining sub-lethal damage.

Recovery has been described in terms of the dimensionless quantity, N/N_o, where N was the recovered cell concentration at any specified time and N_o was the initial cell concentration at time 'zero' prior to exposure of the cells either to high intensity microwave irradiation at 915 MHz or to conventional heating at 49°C.

Acknowledgements

I am grateful to Mr. M.A. Hossain for his consultations and help, and to Dr. A. Goldson, Chairman of the Radiotherapy Department, College of

Medicine for his help. We are grateful to the General President, Dr. T.N. Khoshoo, for giving me an opportunity to deliver this lecture on useful management of the most prevalent electropollution. Supported in part by an institutional grant from the U.S. National Institutes of Health.

REFERENCES

Blackman, C.F., S.G. Benanne, C.M. Weil and S.S. Ali. The effects of microwave exposure on bacteria: mutation induction. Biological effects of EM waves, selected papers of the USNC/WRSI annual meeting, Boulder Colorado 1: 406–413, 1975.

Clark, C.W., L.D. Winter and Z.T. Ordae. Thermal injury and recovery of *Streptococcus faecalis. Applied Microbiology* 16: 1764–1769.

Cleary, S.F. Cellular effects of EMR. In: Om. P. Gandhi, (ed.) *Special Issue of IEEE Engineering in Medicine and Biology Magazine* in press, 1986.

Coley, W.B. The treatment of malignant tumors by repeated inoculation of expipolas with a report of ten original cases. *Amer. S. Med. Sci.* 105: 487–490, 1893.

Dailey, L.E. Clinical study of results of exposure of laboratory personnel to radar and high frequency radio. *U S. Navy. M. Bull.* 41: 1052–1055, 1943.

Danier, A. Les Andres Hertziennas ultracourtes de 80 em. *J. Radiol. Electro.* 10 : 193–195, 1936.

Dutta, S.K. Genetic and cellular effects of microwave radiations. A monograph published by the U.S. Environmental Protection Agency EPA 600/1–80–027, pp 1–40, 1980.

Dutta, S.K., J. Choppala, M.A. Hossain, T.H. Bhar and H.S. Ho. Dosimetric measurements and bio-effect studies using TEM Crawford cells. *J. App. & Basic Sci.* 40: 43–52, 1982.

Dutta, S.K., W.H. Nelson, C.F. Blackman and D.J. Brusick. Lack of genetic effects of exposures of selected microbial strains to 2.45 GHz, and 8.5 to 9.6 GHz pulsed EMR. *J. Microwave Power* 14 : 275–280, 1979.

Dutta, S.K. and Om P. Gandhi. Environmental impact of microwave radiations. Plenary session lecture, published by the 68th Indian Science Congress as a book (Sharma and Sharma, eds.), pp. 170–180, 1981.

Dutta, S.K. and R.M. Millis (eds.) Biological Effects on Electropollution: Brain Tumors and Experimental Models. Information Ventures Inc., Philadelphia, PA., 1986. (In press).

Dutta, S.K., A. Subramoniam, B. Ghosh and R. Parshad. Microwave radiation-induced calcium-ion efflux from human euroblastoma cells in culture. *Bioelectro-magnetics* 5 : 71–78, 1984.

Ely, T.S., D.E. Goldman, J.Z. Hearon, R.B. Williams and H.M. Carpenter. Heating characteristics of laboratory animals exposed to centimeters microwave. U.S. Naval Medical Res. Report NM001256–13–02, Vol. 15 : 77–82, 1957.

Fleming. Microwave radiation in isolation to biological system and natural activity. *In: Biol. Effects of Microwaves Radiation*, Plenum, New York, 1961.

Frohlich, H. Coherent electric vibration and the cancer problem. *IEEE Trans. Microwave Theory Tech.*, 26 (8) : 613–618, 1978.

Furedi, A., R. Valentine. Factors involved in the orientation of microscopic particles in suspension influencedly radio frequency fields. *Biochem. Biophysic. Acts.* 56 : 33–36, 1962.

Goodman, R., L.A. Bassett and S.A. Henderson. Pulsing electromagnetic fields induce cellular transcription. *Science* 220 : 1282–1285, 1983.

Graut, E.H. Determination of bound water in biological materials from diselectric measurements. *In: Physical Basis of Electromagnetic Interaction with Biological Systems*, L.S. Taylor and A.Y. Cheung (eds.), Pub. No. 78–8055, Department of Health, Education and Welfare, Washington D.C., 1980.

Grundler, W., F. Ehilman and H. Frohick. Resonant growth rate response of yeast cells irradiated by weak microwaves. *Phys. Relt.* 62A : 463–465, 1977.

Hahn, G.H., S. Rockwell, R.F. Franklin and L.F. Gordon. Repair of potentially lethal damage *in vivo* in solid tumor cells after X-irradiation. *Cancer Res.* 34 : 351–354, 1974.

Heller, J.H. and A.A. Teixeira. Certain physiologic and pathologic effects of microwaves. *Elect. Eng.*, 70: 239–241, 1959.

Herrick, J.F. and F.H. Krusen. Certain physiologic and pathologic effects of microwaves. *Electrical Eng.* 70: 239–241, 1953.

Labanova, E.A. Microwave effects on the CNS. Polish Medical Publisher, 109–118, 1974.

Lancranjan, I. Gonadic function in workman with long term exposure to microwaves. *Health Physic.* 29 : 381–383, 1975.

LeVeen, H.H. and S.P. Waprick. Tumor eradication by radio frequency therapy. *J.A.M.A.* 235 : 2197–2224, 1976.

McRee, D.I. and H. Gilbert. The effects of microwave radiation on the vitality of isolated from SP nerves. *Radiat Res.* 82 : 536–546, 1980.

Phillips, R.A. and L.J. Tomach. Repair of potentially lethal damage in X-irradiated Hela cells. *Radiat Res.* 29 : 413–432, 1966.

Prohofsky, E.W. Microwave frequencies and the structure of the double helix, the physical basis of EM. Interaction with biological systems. Publication No. 78–8055. Taylor, L.S. and Cheming, A.Y. Eds. Dept. of HEW, Washington, D.C., 1978.

Maniatis, T., E.F. Fritsch and J. Sambrook. *Molecular Cloning: A Laboratory Manual.* Cold Spring Harbor Laboratory, New York.

Raji, M.R. and M.E. Bowden. Effects of high-peak pulsed electromagnetic field on the degeneration and regeneration of the common peroneal nerves in rats. *J. Bone & Joint Surg* 65B(4) : 978–992, 1983.

Schapitz, F.J.F. Psychological manipulation using modulated EM fields. USNC/URSI Adn. Meeting. Boulder, Colorado, Vol. 1 : 9, 1975.

Schwan, H.P and K. Li. Hazards due to total body irradiation by radar. *Proc. IRE*, Vol. 44, pp. 1572–1574, 1956.

Sheikh, I.H. Cellular and genetic effects and recovery of heat damaged cells of *Saccharomyces cerevisiae* by low intensity EMR at 915 MHz. Ph.D Thesis, Howard University, 1984.

Simpler, A.T., A.M. Lilienfold, B.H. Lohm and J.E. Westtake. Radiation exposure in parents of children with monogolism. *Bull. John Hopkins Hosp.* 117 : 374–376, 1985.

Singler, A.T., A.M. Lilienfeld, B.A. Cohn and J.E. Westtake. Radiation exposure in parents of children with monogolism. *Bull. John Hopkins Hosp.*, 117 : 374–376, 1965.

Szmigrelski, S., M. Luczak and M. Wiranowska. 3GHz microwave effects on irons application. *Annal. of the New York Acad. Sci.* 247 : 263–274, 1975.

Webb, S.J. and M.E. Stoneham. Resonance between 10^{11} and 10^{12} Hz in active bacterial cells as seen by laser raman spectroscopy. *Phys. Letters.* 60A : 207–211, 1977.

16

Genetics, Culture and Environment in Tribal Health in India

S.C. Tiwari

Section of Anthropology and Archaeology

The cultural and biological evolutions of man are constantly affected by the environment to which he adapts. How the environmental degradation increasing with the passage of time will affect the evolution and survival of man is one of the important questions pertaining to human existence. It was hoped that the application of sophisticated technology would solve all human problems. However, an exponential population growth coupled with the introduction of higher technology instead of solving human problems have raised them multi-dimensionally. Today man is exposed to the stressed biosphere, a product of his own technology.

Man is subject to the same biological laws that apply to other animal species but, through his culture he successfully moulds himself and his environment, directing to a certain extent his genetic future. With other animals we share the same biosphere but through the intervention of cultural innovations we have implemented our own biology and shaped a living, diametrically different from other animals. Culture stands out a fact *par excellence* in the case of human beings, but it should not give the impression that our biology is relegated to the background. The holism of anthropology is reinforced if we examine the never-ending interaction between culture and biology. Our biology influences our culture and our culture influences our biology.

It is a true paradox that man's cultural and technological advancements are proving detrimental to his survival. Technological innovations have been accompanied by several disfunctional consequences. Man could survive and successfully propagate in areas extremely unfavourable to his existence through cultural and technological means. Even at the lowest stage of survival, the hunting-gathering stage, he overwhelmed the existing fauna and flora. Subsequently, with the acquisition of agriculture, he altered not only the surrounding biotic environment but also the soil profile, forests and hydrology of the surrounding biosphere.

Man sustains himself in different environments through his cultural and biological adaptations, reinforcing each other. Human groups effectively survive in a given ecozone and culture constitutes an important means by which people evolve social behaviours, contributing to their ability to survive and propagate in that habitat. Leslie A. White has aptly stated that "Features of the natural habitat become significant only when and as they are introduced into cultural systems and become incorporated in them as cultural elements." Through the means offered by culture, man adapts himself to the changing environments. A lucid account of culture theories as 'cultural adaptation' is given by Keesing (1974). When man lived in relatively small isolated groups in ecological surroundings, he did not disturb the prevailing ecosystem. In the vicinity of human settlements there existed a bond between certain faunal and floral species which was always mediated by humans causing some species to perish while others survived. The relation between resources and population was always variable as some human settlements were characterized by an abundance of resources, while others remained poor and hostile, thus forcing humans to migrate to other congenial areas.

As resources available to different human societies are variable, they exhibit variation "due to differences in geographical environment, technological equipment, and what may be called the historically determined perception of the exploitable environment" (Fried, 1967). There is a total dependence on forest resources during the hunting-gathering stage, therefore, the relation between culture in the broad sense and nature remains important at the earliest and most elementary level of culture. With the progress of cultural evolution, man acquires control over other resources as offered in the stages of horticulture, pastoralism, agriculture, and modern industry. Man's cultural apparatus is enriched at every stage. Cultural evolution, being additive in nature, overtakes the biological evolution. Therefore, conceptually speaking, it is not the human being that adapts to nature but his socio-cultural system which uses and exploits the resources of the environment. Broadly speaking, man's biological survival depends on the interaction of his culture and environment.

Besides the socio-cultural level, adaptation occurs at the genetic level also. Selection, acting upon the genetic variations, may lead to adaptation. Even at the phenotypic level, the organism may respond to the circumstances prevailing during ontogeny. Several problems of fundamental importance emanate from the conceptualization of 'adaptation' in biology. Understanding the mechanisms of biological adaptation is one of the important questions. Its comprehensive study has to be within the context of evolutionary processes. It operates through natural selection, bringing about heritable changes in an organism by way of mutation. A functional explanation of the change in a particular species can be given by employing adaptation as an important conceptual tool. Most of the non-human living forms have species-specific tolerance for environmental stimuli like, temperature, moisture, altitude, etc. and outside this they cannot exist like, for example, polar bear. In human beings also, there are genetically determined ranges of certain variables and a fluctuation in this range is beyond the tolerance limit of man. An ecological transformation puts considerable stress on the human species and despite a certain amount of adaptation, it remains basically of short term advantage. This is amply demonstrated in the present environmental crisis.

Considerable genetic variability is manifested by the human species which is maintained and propagated by factors like mutation, genetic drift, natural selection, isolation of populations and breeding structures etc. The survival value of man depends on his intelligence, largely determined by social and also biological factors. A Darwinian component of natural selection, 'survival of the fittest', does not hold valid for the humans since 'unfit' people have equally good chances to survive and propagate. Had selection operated, most of the so-called 'inferior' genotypes or 'unfit' people would have been eliminated. But the fact that they have survived shows that selection forces were nullified before cultural evolution on the one hand and a highly differentiated division of labour on the other. A person of low intelligence and genetic deformity may be perhaps more successful in producing fertile children.

The problems of tribal health cannot be studied in isolation from the general population of India. According to Polunin (1977) "Tribal people suffer from the same diseases as other peoples with the marked preponderance of infective over degenerative diseases." The tribals are exposed nearly to the same health problems and diseases as most of them do not form isolated pockets. Those who have remained isolated will soon be exposed to the rapid pace of development and industrialization in our country. Therefore, it is appropriate to study the problems of disease and health in a general way before the specific problems of tribal health are delineated.

Although in the early stages, the ecosystem was not subjected to any mass devastation, man was constantly under the duress of infectious diseases. It is also true that a number of infectious diseases which have been generated with urbanization and modernization leading to the disastrous changes in ecology, were relatively absent in the primitive societies (Black, 1975). These infectious diseases could be caused by viruses, bacteria or protozoan and metazoan parasites. During the hunting-gathering stage, man's subsistence was entirely dependent on wild resources. The availability of the yield was conditioned by the extractive efficiency and seasonality of the resources. The population size was limited and they had to move in small bands. Evidently at this stage there was no significant increase in the population density and because of ecological constraints, they remained isolated. Thus there was no accumulation of human refuse and it did not create sufficient conditions for the propagation of infectious diseases. Like their prehominid ancestors, they were affected by pinworms, yaws and external lice. Apart from this, they probably accidentally transmitted diseases resulting from insect bite, wound and parasite-contaminated food. This included diseases like trichinosis, schistosomiasis and tetanus. Parasitic infections were reduced to some extent with the discovery of fire when man started cooking meat and clothing was introduced.

With the agricultural revolution, primitive man exposed himself to several infections and diseases, so far unknown to him. Introduction of food production led to settled living, leading to concentration of population and increase in density. This resulted in unhealthy surroundings, giving rise to various types of viruses, bacteria and parasites. With an increase in population density, the relationship of man to diseases become more intimate.

The three factors involved in the occurrence of infectious diseases are, the host, the pathogen and the environment. The interrelationship between these conditions led to the propagation and transmission of diseases. Increase in the population density facilitated the spread of disease pathogens. Domestication of several animals like pigs, cattle, sheep and goats, dogs and other animals increased the possibility of dissemination of pathogen carried by these animals. Here the case of the yellow fever virus can be cited. The virus is primarily carried by the monkey and through mosquitoes transmitted to human beings. Again through Aedes mosquitoes and the patient, it was transmitted to the rest of the population. It is well known that Salmonella, a bacterium and Ascaris, a nematode parasite, are transmitted to man through animals. Man fell an easy prey to several infections like tuberculosis by consuming the meat or milk of these affected animals. The incidence of scrub typhus increased when man started digging earth for crop plantation. These examples abundantly show that the evolution of disease patterns, can be correlated with the evolution of the style of life of mankind.

There has been a co-evolution of diseases with the cultural evolution. In all the phases of cultural history, man has interacted with his environment in various ways. Although the aspects of culture are incorporated into the environment in which man finds himself, yet culture does not simply adapt to nature but it appropriates nature and transforms it according to the requirements of man. This transformation of the natural environment with the help of the instruments of culture affects man's relationship to disease vectors. A good example illustrating this can be provided by introspecting the history of malaria infection. The incidence of malaria was non-existent when man was in the hunting-gathering stage due to a small size of population. Moreover he was isolated in small groups because of the nomadic nature. When people started practicing agriculture, particularly in the tropical regions of Africa and Asia, the population density increased resulting in the collection of human refuse in the immediate surroundings. It provided optimum conditions for the propagation of mosquitoes. The mosquitoes harboured the malarial parasite, *Plasmodium falciparum*.

There were large concentrations of human population in the cities which was the next stage in the co-evolution of man and disease. Owing to a polluted water supply which could not be purified as scientific methods were not available, epidemic diseases like typhoid and cholera appeared. Epidemics, unknown in the ancestory of man, inflicted heavy casualties on human populations. Most devastating epidemics like black death or plague caused by Bacillus pests ravaged the greater part of Europe and Asia. One would recall the great epidemic which lasted for three years in Europe (1348–50) and eliminated nearly one-fourth of the European population.

With the onset of industrialization in Europe, the disease pattern assumed a different shape and unknown diseases started appearing. In industrial cities, problems of air and water pollution increased several times assuming chronic dimensions. Industrial wastes and the origin of urban slums generated severe unhygienic conditions. These unhygienic states became the germinating sites of new varieties of micro-organisms, thus differentiating the disease patterns. Typhus, typhoid, smallpox, tuberculosis, diptheria, jaundice and gasteroenteritis assumed virulent proportions during the eighteenth and nineteenth centuries.

Subsequent to the independence of our country, the pace of industrialization considerably increased and the tribal population of India, hitherto isolated, was affected by the industrial growth though in varying proportions in different areas. The so-called cultural isolates started breaking down. The encroachment of commercial frontiers initiated by industrialization in the tribal areas contributed to vast magnitudes of change. If on the one hand, the tribals were being engulfed by the wider world, on the other the tribal areas adopted several cultural traits and practices emanating from outside. In certain areas, the tribals were practically forced to migrate to industrialized towns as industrial labour force and had to settle in slum areas, characterized by degraded human existence. The slum-living of the tribals in an environment, completely detached from their modes of living, exposed them to the new patterns of diseases and disorders.

During colonial expansions, several new diseases like syphilis and measles were introduced. These diseases, for example, were unknown to the Hawaiians but were introduced by the whites during their colonial expansions. Improper sanitary conditions prepared the ideal ground for the spread of infectious diseases. Several human miseries emerged as by products of science and technology and sometimes they assumed disastrous proportions. These often shake our beliefs in scientific and technological achievement.

Medical science has developed powerful drugs to combat several diseases. Out of many effective drugs, one is the group of antibiotics which has resulted into a phenomenon called 'infectious drug resistance'. Due to indiscriminate use of antibiotics for everything from the common cold to complex situations, the drug has raised certain disturbing factors. More recently, Acquired Immunity Deficiency Syndrome (AIDS) is threatening the human populace and so far there seems to be no answer to it. In several affluent countries, antibiotics are mixed up with animal feed to protect them from infections, thereby making several microorganisms drug-resistant in these animals. A good example is that of Salmonella which causes typhoid fever and is transmitted to human populations if they consume animal meat thus infected. Antibiotics in the course of time may lose their effectiveness if administered indiscriminately.

In several countries DDT was sprayed as insecticide to destroy agricultural pests like the Mediterranean fruit fly (*Drosophila melanogaster*) but it resulted in eradicating the harmless and beneficial ones as well. It caused the development of a hardier fruit fly through mutation which passed on this capability to succeeding generations.

Generally, most of the biological species occupy a particular niche but in man these boundaries are indiscrete and he adapts himself physiologically as well as morphologically to changing environments. Man has genetically isolated himself from other groups of his species and culture maintains this isolation. The caste system, a pan-Indic characteristic, maintained isolation between different groups. Breeding between various populations is maintained by physical and cultural isolations. However, even among the isolated tribal groups "There are also always human influences from outside the groups" and these influences are coming from "settlers, traders, officials, missionaries, tourists and others" and as a result almost everywhere, "some artefacts and exotic microbial agents will have been introduced" (Polunin, 1977). The genetic diversity and a changing biosphere together with the interaction between them has resulted in the dynamic changes in human populations.

With industrialization, a new group of diseases has emerged, termed as 'occupational diseases'. They concern the discipline of industrial medicine and are caused due to a great range of chemicals used in industries. The effect of some is immediate; with others the effects are delayed and may perhaps cause a deadly disease, like cancer in middle or late life. Those who work with lead and mercury are exposed to various blood diseases—silicosis is associated with mine workers. Asbestosis is common with people working with asbestos. There are several other examples illustrating the list of 'occupational diseases.'

With a considerable expansion and development of transportation system, a vector is transferred within hours which in earlier times would have taken a couple of years. The modern transportation system causes an easy dispersal of diseases affecting a large segment of human population. The world is endangered by the constant threat of dissemination of drug-resistant viral and bacterial pathogens. Most of the nefarious types of influenza viruses travel at rapid speeds from one continent to the other. The panic caused by the Asian flu in 1968 is still fresh in our memory.

With an emergence of nuclear technology, the most beneficial application of atomic power is overwhelmed by an inherent danger involved in its uses. In the final analysis the potential perils of the nuclear technology seem to be significantly higher than its peaceful and benevolent uses. The thermonuclear tests performed by the super powers every now and then have led to serious radioactive fallout spreading into the biosphere. This is in addition to the ionizing radiation from our solar system which continuously penetrates the atmosphere acting as a mutagenic agent.

It is true that man reigns supreme in technological evolution. He is also the supreme product of biological evolution. Given a combination of both biology and technological advancement (culture), he can have tremendous improvements in biological and cultural spheres. But his cultural evolution has variously exposed him to several dangers. He has spread myriad atmospheric pollutants which besides altering the climatic cycle have also put considerable stress on the human gene pool. The smoke released by industries contains a fair amount of carbon monoxide, lead and several other chemical pollutants accumulating strain on human populations. When the protective natural vegetation is removed and the extremely thin layer of the top soil is eroded by agricultural practices, the exposed fine iron rich clay is converted by oxidation into a rock hard material. Loss of vegetation has resulted in changing the climate and hydrology of the area. Resulting from cultural activities like burning of fuel, industrial burning, chemical fumes and other engines have led to the escalation in the level of carbon dioxide. The dust layer along with carbon dioxide has produced the turbidity of the atmosphere.

It is because of the infusion of nitrous oxide in the atmosphere, that the ozone shielding the biosphere from ultraviolet radiation is reduced, thus increasing the risk of skin cancers. These atmospheric pollutants cause bronchial asthma and emphysema. Man undoubtedly possesses the genetic capacity to adapt to environmental stresses but this capacity is however not unlimited.

More than half of human mortality was known to have been caused by malaria in the past. By employing an organochlorine compound, DDT (Dichloro-diphenyl-trichloride-ethane), the mosquitoes causing malaria were eliminated, as also were crop damaging insects. Although certain controversies exist about the safety levels of DDT, there are reasons to believe that it causes cancer and other pathologies. The disturbing fact about DDT is that it is not biodegraded as a result of which it is passed on from the body fat of one animal to that of another. Another group of chlorinated hydrocarbon compound in polychlorinated biphenyls (PCB) also causes widespread pollution. The Bhopal gas tragedy is still fresh in our memories. Tapan Bose has aptly characterized it as 'peace-time Hiroshima.' Today, the tribal populations of India are emerging after a transitional phase, into a totally new type of environment which of course is not their own creation.

We are faced with a situation where harmful mutations are taking place at a much higher rate than they could be eliminated. We are exposed to several dangerous mutagenic agents, chemical as well as radiational, impinging upon human material almost unremittingly. Consequently, these are not only lethal to an individual but may alter the genetic constitution of future generations by contributing to various types of malformations. Unfortunately, many of these mutagens are unknown and unreported. Some of the food preservatives particularly in sweets, for example, may not be harmful by themselves but may produce metabolites which may potentially cause harm to the human system. It may not be possible to investigate all pollutants in the environment. Till today, the total effects of nuclear bombs exploded during the Second World War on Hiroshima and Nagasaki are not fully known to us. It is true that chromosomal abnormalities were found in individuals exposed to the blast *in utero* and on adults the effect was leukemogenic. In terms of the nature, new favourable mutations will be comparatively rarer since the existing species of mankind is the result of past selection that brought it close to the best possible adaptation to the environment it occupies.

The environmental influences on the genotype could be those that are experienced after birth. One important factor which affects the genetics and future development of the child is the maternal uterine environment. At one time it was thought the foetus is insulated from the external environment within the maternal womb, but it is well known that this is not true.

The human embryo is sensitive up to eight weeks to external environment. There are several factors which lead to structural and functional disorders, like young mothers who bear more deformed children and suffer the highest mortality in child birth. They also show higher incidences of miscarriage and still birth. With advancing age of the mother, risks of still birth, miscarriage, birth of deformed children and *maternal mortality rise*. Penrose (1963) enumerated death at different periods of human life as given below:

1. Pre-natal deaths	15 per cent
2. Of the remainder there are:	
a) still born	3 per cent
b) death of the newly born	2 per cent
c) death before maturity	3 per cent
3. Of the survivors:	
a) those who do not marry	20 per cent
b) those that remain childless	10 per cent

Thus nearly 53 per cent do not reach reproductive stage because of one or the other reason. We do not have the estimates for the tribes but it seems reasonable keeping in view the socio-cultural matrices in which the tribals are placed that perhaps casualties would be more in the first and second categories than in the third. Till the time we do not have empirical data on the tribes, our observations will remain mere speculation.

Previous child bearing experience of the mother is also important. It has been observed that first born and latest foetuses are less likely to survive and foetal malformations are more common. Mothers at an advanced age show an increased frequency to give birth to mongols and hydrocephalic babies. Non-infectious disability of the mother is likely to affect the development of foetus. Toxaemias can affect the brain development of child. It can also lead to behavioural problems in the child. Diabetes and several other diseases can also damage the foetus. Mothers exposed to adverse occupation, health, general hygiene and sanitary conditions may have problems in the foetus. Among several tribal families due to insufficient and poor nutritive food, organic deficiencies are caused in the mother which may influence the development of child. In many tribal groups, foetal rickets are common due to malnutrition.

During the first three months of pregnancy, viral infection or bacterial and protozoal infection can pass through the placenta to the foetus. Infections which specially affect the foetus are *polioxmyelitis*, smallpox, measles, mumps, scarlet fever and several bacterial infections.

Syphilis is passed on to the foetus in the early pregnancy period and may cause miscarriage if acquired later during pregnancy. It can cause blindness, deafness, defect of heart and infection can cause microcephaly, idiocy and mental retardation. Nearly 23 per cent of the human population dies before birth or shortly afterwards.

Drugs administered to pregnant women can adversely affect the foetal development. It is difficult to assess the effect of drugs taken during pregnancy. However, some drugs like thalidomide have been proved to be dangerous. It is suggested that heavy smoking by mothers during pregnancy can lead to premature birth of the baby.

Many tribes in India are known to consume different types of herbs during pregnancy. Many of these herbs may cause genetic or developmental errors in the unborn child. Large number of these herbal folk medicines may be neutral but some of them may cause developmental abnormalities (teratogenic). The potential effect of a number of these herbal drugs consumed by the tribal women is unknown. Foreign substances taken during pregnancy may be harmful to the development of child. During pregnancy several prescribed and unprescribed drugs are consumed and their effect on the foetus is yet to be ascertained.

The tribes of India represent various phases through which man has passed since the palaeolithic times. Palaeolithic or Neolithic cultures exist or had existed a few hundred years earlier among the Andaman Islanders or the Vedas of Sri Lanka. Early iron age culture, combined with shifting agriculture are predominantly found among the tribes of North East, Central and South India. Primitive urbanized situations exist in some parts of India among the tribal populations. The WHO expert committee on Research in Population Genetics in Primitive Groups rightly observed that such tribal groups "present both in their size and level of economy, the closest approximation one can find to the conditions under which man has lived for the greater part of his existence. It is probable that most of the genetic endowment of modern man has been shaped by the action of natural selection and other evolutionary processes at these cultural levels."

Our ancestors of the late Palaeolithic age were basically nomads. The inventions of the polished stone age enabled mesolithic men for the first time to attack the trees of the forests. This led to the Neolithic period and during this period forest areas were cleared and used for agriculture and timber was used for making houses and other useful articles. The earliest form of agriculture was 'shifting' agriculture and it was soon followed by the settled agricultural system.

The disease pattern and the resultant mortality pattern might have been different at various period of history. A survey of life spans at different times of history was constructed by Deevey (1960) for human longevity.

Neanderthal	29.4 years
Upper Palaeolithic	32.4 years
Mesolithic	31.5 years
Neolithic (Anatolia)	38.2 years
Bronze age (Austria)	38.0 years
Classical Greece	35.0 years
Classical Rome	32.0 years
England (1276)	48.0 years
England (1376–1400) (Plague)	38.0 years
United States (1900–1902)	61.5 years
United States (1950)	70.0 years

Today the Japanese have extended the life expectancy to 80 years.

In course of time, shifting agriculture was gradually replaced by settled agricultural methods, irrigation and more sophisticated farming implements were introduced. The digging stick evolved into the hoe, the spade and finally the plough. Consequently, wealth increased and new trade routes were opened rapidly. Many parts of the Earth suffered with epidemic diseases. Major areas from China to Europe were ravaged with plague and millions died. The disease occurred at times when people were in poverty and lacked resistance.

As a result of man's defiance of ecological laws in crowding himself in villages and cities led to the introduction of diseases hitherto unknown to him. Thus with the introduction of shifting cultivation in the hilly areas of Malaysia, more sunlight was available due to felling of trees, which encouraged multiplication of *Anopheles maculatus* resulting in greater incidence of malaria (Polunin, 1963). Some diseases are peculiar as only man gets afflicted and there is no animal source of infection. They are also dependant on population density. There are few diseases which are limited to tribal people only. One of the classic examples of such a disease is Kuru, which is confined to New Guinea Highlands only due to its unusual mode of transmission and the distribution of the agent (Gajdusek, 1973).

Many of the diseases are genetic in origin and manifestation of some of these genetic disorders depends largely on the environmental interaction. Genetic heterogeneity in the human population can be interpreted in terms of incidence of infectious diseases. Certain genotypes provided resistance against particular diseases but the protective mechanism may not be of use when pathogens appear. In every human population, there are some individuals who may possess a natural immunity or resistance against potentially dangerous new viruses. A good example of this is provided by sickle cell anaemia developed as a protective mechanism against malaria despite its lethality in the homozygous state. During the earlier part of man's history, the detrimental genes were either absent or rare but with a high population density, these genes had better chance to disseminate in the human population. Infectious diseases become more prevalent with dense populations.

Apart from the diseases genetic in origin, there are various communicable and non-communicable diseases. They are caused by viral and bacterial pathogens, protozoa, insects and worms etc. In India, we are familiar with the incidence of devastating communicable diseases like plague, cholera and small pox. There are non-communicable diseases like malaria, tuberculosis, leprosy, blindness, etc.

Among the viral diseases, measles and viral hepatitis are common among the tribals. As a result of unhygienic conditions contaminated food and water, and inadequate sanitation, bacterial infections like enteric fever, diarrhoea, dysentery and cholera become endemic. Among parasite diseases, malaria is still widespread.

Some tribal zones are found to have a very high frequency or cerebral malaria.

Malnutrition is an important cause of mortality among the tribals. There is accumulating evidence that protein deficiency in pre-natal and post-natal development phases of human infants results in smaller, underdeveloped brains. Presently, this biological and social disaster is common in India. It would further proliferate in an overpopulated and protein scarce areas. In most of the tribal areas particularly among children, we have kwashiorkor characterized by a swollen belly, sluggish liver, and progressive wasting caused by protein deficiency. Shortage of Vitamin D results in development of rickets. Iron deficiency in their food leads to iron deficiency anaemia.

The disease pattern in the tropical and temperate climates has a fundamental difference. In countries with hot climate, diseases are transmitted by insects and other intermediate vectors. These insects and vectors do not thrive in the cold climate since during severe winters they may die. In hot countries, vectors transmit protozoan and helminth parasites.

Polunin (1977) observed that "The more favourable an environment the more species it contains, and complexity reaches its peak in tropical rain forests." Dunn (1968) suggested that the number of parasitic helminths and protozoa increase or decrease according to environmental situation. He observed that more than twice as many parasites are present in the hunter-gatherers of luxuriant rain forests of Africa and Malaysia compared to Bushmen of the Kalahari desert and Australian aborigines whose habitats are poorer and contain fewer species.

In the tropical area more than 20 per cent of the children die before reaching reproductive age as they are afflicted by insect borne and similar diseases. The effect of this is more severe on settled populations than nomadic since parasites and vectors spread easily in large settled populations. One such disease was malaria which a few years earlier was nothing short of a disaster. One may realise its magnitude by the fact that more than half the human casualties were caused by malaria. Besides malaria, yaws became prevalent in wet and hot tropical climate. Yaws are also transmitted from one person to another and cause severe lesions of the bones. A few years earlier yaws was endemic in Jagdalpur and some other districts of Madhya Pradesh but it was more or less controlled by the efforts of WHO. However, it was not eradicated. Saxena et al. (1971) reported the presence of "some peculiar tribal disease causing filaria like swelling of legs." Their preliminary investigations point out that this could be "a problem of resurgence of yaws".

During a number of years of living in crowded and insanitary conditions, tribes in India have developed several human pathogens. Shigella dysentery causes acute and often fatal dysentery but there are allied organisms which cause greater damage. The disease which has increased in recent years is enteric infection resulting from consumption of contaminated foodstuffs and water infections. Hepatitis is widely prevalent due to the contamination of food and water. They consume water drawn from surface water and the virus can survive for long periods. The diarrhoeal diseases are supposed to cause one-third of all infant deaths specially under the age of five. Kaur et al. (1984) conducted a survey of anaemia in tribals of Adhaur and reported a high prevalence of iron deficiency anaemia (62.3 per cent) and hookworm infection in 68 per cent of the population.

As a result of industrialization, a new group of diseases termed as 'development diseases' have emerged among the tribal workers in factories and mines.

Mine workers develop silicosis, asbestosis and pneumoconiosis. They leave their homes to earn wages in the factories and live under extremely unhygienic conditions in the slum areas.

There is little realization of the profound effects on disease ecology that have resulted in the tribes of India due to deforestation. Tribal economy was always integrated with ecology but the balance and equilibrium were never disturbed. Today it appears that the material resources are depleted almost entirely in some areas and unless corrective measures are taken it can become a major problem.

Efforts during the five year plans to recover the lost green cover and develop lost forests for domestic and commercial demands have produced insignificant results. The focus all along has been solely on the insular aspect of the forest development of both forests and tribal resources as integral parts. Considering the magnitude of the problem of reclothing the denuded and impoverished forests and an ever increasing demand for supply of wood with a spiralling rise in human population, development activities will have to be substantially stepped up. There are several disquieting features which are clogging the development of forests and forest resources like collusion of contractors with forest officers and other senior officers of the bureaucracy.

The planning has to be oriented to the immediate beneficiaries from the forest resources in the tribal areas. It has to be ensured till alternative resources of livelihood for those tribals who depend for this on the forests are found.

Every year, on an average, plantings are done on only 0.4 million ha and against this 1.5 million ha are losing the forest cover. Unfortunately, it is not being realized that denudation of one ha of hill forest is 50 times more damaging than the deforestation of similar land in the plains. The forests are the regulator of all basic resources—soil, water and air, and are the ultimate determinant of all economic activities.

With deforestation, the tribals in Bastar area in Madhya Pradesh have given up their life styles now practised in remote areas like Abujhmarh. With their most important economic resource destroyed or depleted and few of them employed in the mines, the Maria tribals today are a demoralized lot.

Many studies have been conducted to study the socio-cultural profile of the tribal groups in India. But very few studies have attempted to study the traditional system of disease, diagnosis and treatment in the tribal societies. More studies in this direction will definitely be useful exercises as they will reveal the dynamics of health, disease and illness in tribal areas. The problem of tribal health was unfortunately never taken seriously both by the government agencies and the medical profession. Social scientists ignored this area in their detailed ethnographies and a few reports available on tribals are not only peripheral but casual in their approach. To put it rather bluntly, the social science understanding of tribal health is in shambles. For a meaningful understanding of tribal health care and to find out how under the existing social, economic and cultural settings these needs can be best met to the satisfaction of the people, we need to adopt strategies and methodologies which integrate their traditional methods with western medicine, in primary health care that is promotive, preventive, and curative and their implications in the tribal health care.

Even in the simplest tribal societies, the practice of conventional medicine is not a homogenous tradition. It gets complicated by specialized methods of traditional medicine, parochial healing traditions or practices such as divination, as well as many forms of magico-religious or ritual healing. In other words, the domain of primitive medicine overlaps with the notions of magic and religion.

The definition of illness as elucidated by the biomedical principles and the way in which the tribals define and perceive a disease is fundamentally different. The biomedical principles for health care and sickness, to a very large extent, are not defined within the parameters of socio-cultural values. According to the biomedical principles, the disease could be defined as a deviation from the normal physiological functioning. It has certain specific etiology. The scientific administration of medicine for a specific ailment is based on a diagnosis of the disease.

Jones (1977) stated that "western medicine embodies a concept of sickness as conditions which are biologically and physically determined" and the patient is "the object of the physicians on surgeons procedures". In this procedure patients "participation in and initiation of action in deciding the treatment prescribed by the doctor is given relatively little emphasis."

Lewis (1977) observed that "In our western medicine we turn our clinical attention chiefly to the patients body. Observations of how it is disordered may guide the choice of appropriate treatment. Whether the patient is a generous, God-fearing man, or a disputable slanderer makes no difference to how disease and treatment will work on him."

On the other hand, in many tribal communities medical care, treatment and etiology of a disease are defined with in the social context. The illness may be attributed to evil eyes, black magic or may be envisaged as resulting from offending some spirit or deity. In almost all the tribes the treatment of disease is done through either folk medicine, or learned magico-religious curing systems or a combination of both. There is a wide range of classification of illness and etiology in the tribal system and in turn the choice of treatment is based on the diagnosis of the ailment. According to Lewis "they look for answers in justice, right and wrong conduct, malice, motive and purpose. In these they may find a reason for their sense of suffering and harm. Such an answer about why it happened may also suggest a way to control or correct the situation." Their view that the "illness does not come casually and unmotivated, but serves to harm, punish, or warn, usually requires a diagnostic frame wider than that given by the patients body with its intrinsic signs. The sick man's conduct and social relationships must be looked into to find the circumstances or action that provoked his illness." Jones (1977) argued that the non-western traditional system "emphasizes the person as being an actor, to be counselled, prompted and brought to a viable state in a network of social relations. Rituals and ceremonies of dance, drumming, fasting and the use of narcotic or psychedelic substances and the use of trance states are frequently a part of this." In comparison with modern living "tribal man has to be largely content with his simpler technology and with magico-religious manipulation" (Polunin, 1977).

In the tribal system, each illness episode takes into account the social characteristics of the individual and the social situation before undertaking a particular sequence of treatment procedure. There is a considerable importance of individual, family, kinsman, religious leader like diviner, *ojha*, mystics, ecstatics, *shamans* and priests in the treatment of the afflicted person. The power to make the choice in the legitimation of illness and in seeking treatment of the disease lies primarily with the individual family and to some extent on the kinsman.

In the traditional system of curing the diseases, culture affects the way in which patients and healers perceive and define illness and influence the choice and decisions with respect to the treatment of the illness.

Thus we are confronted with two models of treatment, that is, the western biomedical system and the traditional healing system practiced by the tribals. A person suffering with high fever sometimes starts whispering in an incoherent way. Under the biomedical system, it is called delirium and efforts are made to bring down the temperature of the patient. However, in a traditional healing system, these symptoms are diagnosed as characteristics of the patient as being possessed by some malignant spirit. The treatment prescribed for this is more often exorcism, resorted to by the *shaman*. Similarly, a patient suffering from smallpox may be isolated from other members of the community and the prescribed course of treatment may follow in the biomedical system. In the ethnomedical system, it would be attributed to the blessings of a goddess on the patients.

In the traditional healing system, it is imperative to study both the patient and the healer in the context of culture. Like the biomedical system, there are distinct clinical categories in the traditional system for understanding the diagnosis of the disease and its design of treatment. There is a distinct patterning of symptom perception and prescribed treatment. While preparing an ethnomedical profile, it is important to know as to who diagnoses the illness, and what is the relationship of the whole process with the community. This can be juxtaposed with the biomedical system.

In the biomedical system, the clinical diagnosis is basically a technical procedure conforming to certain objective indices. In ethnomedicine, the social processes are inalienably bound to the perception of disease on the one hand and the experience of illness on the other and these are quite different. If former system involves physicians, surgeons, nurses, clinical laboratories and hospitals, the latter involves mystics, ecstatics, *shamans*, priests, other religious healers, shrines, and places inhabited by spirits and powers.

Generally speaking, in most of the tribal societies, a person comes to be defined as ill and diagnosed as a patient by following a particular sequence of diagnosis and prescribed treatment. To substantiate this, let us take an example from Kumaon. A person, afflicted with some ailment, first of all consults the *Gantuwa* or calculator who follows a particular procedure to diagnose the disease and prescribes the treatment which includes the propitiation of some offended spirit etc. If this treatment fails, the patient and his family members or what the medical anthropologists call the 'therapeutic management group,' consult a *Dangaria* (Diviner) who is possessed by a certain specific spirit and in this case the spirit is supposed to diagnose the disease and formulate the treatment. The *Dangarias* also have distinct categories and some of them are more powerful than others. Thus there exists a distinct stratified system of diagnosis in the traditional healing system.

In recent years, modern medical facilities have been extended to some of the tribal areas. Unfortunately, many of these hospitals and even primary health centres are located at a distance, almost unapproachable by the tribals. Nevertheless, we are confronted with a situation where both the systems of treatment exist at the level of tribal societies. It would be of considerable interest to study the interaction of the western biomedical system and the traditional tribal system of curing a disease. This will inevitably open up new vistas of study and added dimension to the tribal health care.

We can examine the problem of tribal health in a wider perspective. The development of health has to be based upon the perception of tribal people of their own problem. We cannot altogether reject their own system of healing and treatment but certainly it has to be gradually supported and substituted with modern medical system. Reporting on tribal medicine as practised by several tribes of Kerala, Mathur (1982) observed that the Paniyans, Kattunaickans and the Adiyans think that "medical aid for smallpox and cholera, to be effective, must be preceded by worship of tribal gods and goddesses. They still believe that if a disease is caused by spirits or supernatural agencies, medical treatment will not be effective, unless the influence of the evil spirit is removed."

I have deliberately avoided the consideration of the genetico-environmental disorders among the tribes of India. It is not because this area of study is unimportant but the basic needs of health care are more important and should come first in our priority list. Today biotechnology—a new and sophisticated ability to alter living organisms to the needs of man—can transform the world. Biotechnology may make it possible to cure some rare diseases caused by defective human genes and treatment may be provided at the cellular level. However, these goals in the present context of tribal health seem unrealistic and unattainable.

There is no denying the fact that most of the illness of the poor tribals derive from the environment in which they live. Here we are including socio-cultural along with the physical environment under the general rubric of environment. It has to be kept in mind that some of the tribal habits, like excessive drinking of country liquor, have caused a number of liver and stomach diseases. They need preventive measures more than curative methods of health care. As long as the concerns of health care and economic integration are unrealized, there is every reason to believe that the material and non material quality of tribal life will not be ameliorated, but will decrease markedly in the absence of the correction of imbalances of these factors.

We are committed to provide health for all by 2000 A.D. To achieve this objective, we should ensure that every baby be born alive and healthy, without injury to the health of the mother and live in full mental and physical health. These goals are neither unrealistic nor unattainable.

REFERENCES

Black, Francis L. Infectious Diseases in Primitive Societies, *Science*. 187: 515–518, 1975.

Deevey, E.S. 'The Human Populations' in Ehrlich et al. *Man and the Ecosphere*. Freeman, 1971, 1960.

Dunn, F.L. Epidemiological factors; health and disease in huntergatherers. *In*: Lee, R.B. and I. Devore, (eds.) *Man the Hunter*, Chicago, 1968.

Fried, Morton H. *The Evolution of Political Society*; *An Essay in Political Anthropology*. New York, Random House, 1967.

Gajdusek, D.C. Kuru in the New Guinea Highlands. *In*: Spillare, J.D. (ed.) *Tropical Neurology*, Oxford University Press, 1973.

Jones, A.D. Medical Practice and tribal communities. Health and Disease in Tribal Societies, 1977.

Kaur, Paramjit, G. Singh and S.S. Pandey. Anaemia in Tribals of Adhaura, Rohtas, Bihar. *Indian Journal of Public Health*. 28, 1; 4–7, 1984.

Keesing, Roger M. *Theories of Culture*, *Annual Review of Anthropology* 3, 73–97, 1974.

Lewis, G.A. Beliefs and behaviour in disease. *In: Health and Disease in Tribal Societies*, 1977.

Mathur, P.R.G. Anthropology of Tribal Medicine: Disease and curing Techniques among the tribals of North Wynad (Kerala). *Man in India*, 62, 295–312, 1982.

Neel, J.V. Lessons from a 'primitive' people. *Science*, 150, 1970.

Penrose, L.S. *The Biology of Mental Defect*. Sidgwill & Jackson, London, 1963.

Polunin, Ivan. The effects of shifting agriculture on human health and disease. In: *Proc. of the UNESCO Symp. in the Impact of Man on Humid Tropics Vegetation, Goroka, Territory of Papua—New Guinea*, 1963.

Polunin, Ivan. Some characteristics of tribal peoples, Health and Disease in Tribal Societies. *Ciba Foundation Symposium 49* (New Series), 1977.

Saxena, V.B., B.S. Darbar and M.K. Jain Resurgence of Yaws, a preliminary report from Jagdalpur district, M.P., India. *Indian Jour. Prev. Soc. Med.* Vol. 9, No. 2, 41–46, 1971.

W.H.O., Expert Committee on Research in Population Genetics of Primitive Groups. *W.H.O. Tech. Rep. Ser. No.* 279, 1964.

V

HEALTH SCIENCES

17

Perspectives in Urban Health in India

V. Ramalingaswami

The Indian Urbanization Process

URBAN POPULATION

At first, I would like to recapitulate some features of the Indian urbanization process. *India has the third largest urban population in the world.* The urban population in the 1981 Census stood at 156 million, which represented 24 per cent of the total population. This is distributed in 3256 settlements—in 12 metropolitan cities with 1 million or more population accounting for 27 per cent; in 216 cities, each with 100,000 or more of population accounting for 60 per cent of the urban population. Between 1971 and 1981 while the overall population of India grew by 25 per cent, the urban population grew by 46 per cent. About half of the increase in urban population is due to natural growth and the other half to fresh immigration. Estimates speak of the urban dwelling *population reaching a figure of 350 million by 2000 A.D. doubling from the present figure like the proverbial Lily Pond*, which would then *place India in the first position with regard to the size of its urban population, an awesome prospect*!

URBAN SLUM POPULATION

The result is over-crowding of built-up places, squatter settlements and unauthorized colonies leading to *slum formation*. A characteristic feature of slums is the imbalance between the number of people and the availability of amenities and services. Twenty per cent of India's urban population lives in slums; in the big cities it ranges from 10 per cent in Bangalore, to 37 per cent in Kanpur, to 38 per cent in Bombay and 42 per cent in Calcutta. Forty per cent of all slum population lives in 10 metropolitan cities. One estimate says that by 2000, 50 per cent of the population in millions and in cities will be dwelling in slums.

It should be noted at this point that the pace of urbanization in the industrialized countries has passed its peak and the urban population seems to have stabilized at around 70 per cent on an average. This is due to low fertility rates, more equitable spread of public utilities and balanced investment in agriculture and industry. *The Third World urban pool has reached the point that it is poised for doubling in less than 15 years.*

PHENOMENOLOGY OF URBAN SLUMS

Numbers alone do not tell the full story, which is one of destitution and abjectness enveloping urban slum life in a chaotic and uncontrolled manner.

Urban Heterogeneity

A striking feature is the profound heterogeneity of the city with its contrasts, competitions and stigmas. We talk about urban averages. For example, the average infant mortality rate is lower for the urban population than for the rural, almost half, but unless we disaggregate the averages in terms of rates for the slum areas and the more well-to-do sections of urban society, we get a meaningless and misleading picture. Infant mortality rates in urban slums are much higher than the averages for the urban population as a whole.

For example, in a recent study carried out under the auspices of the ICMR it was found that in the urban slums of Madras, Delhi and Calcutta, the infant mortality rate ranged from 54 to 91 per 1000 live births. Almost 40 per cent of the mortality is accounted for by neonatal mortality. The picture in the urban slums with respect to maternal care is equally disturbing. The ICMR study referred to indicates that a large number of deliveries in the slums of Delhi, Calcutta and Madras still take place in the slums themselves without assistance from any trained health care person. These cities abound in glittering tertiary care institutions. Urban averages thus hide deep human tragedies.

The Unfriendly City

Much has been written about the unfriendly city where the newly arrived migrant who has detached himself from whatever social support systems he had earlier in the village is now a floating piece of humanity with very little social infrastructure on which he can lean, living in isolation often among multi-lingual groups, each one pushing, jostling and pulling in various directions. This is the social environment into which the urban immigrant enters.

Spatial Distribution of Slums

Another feature is the spatial distribution of slums in relation to relatively better-off areas. The picture varies. The nature of work and commuting costs generally induce urban slum settlements to be close to their places of work. Recent experience in Bhopal warns us that locating people close to industry which deals with hazardous chemicals would be unwise.

A feature of the Indian scene is that at least half the migrants from rural to urban areas belong to the younger, less than 35 years, age group and over half of them are illiterate or semi-literate (State of the Environment 1982, Department of Environment, New Delhi).

Health in Urban Slums

THE DOUBLE BURDEN

The health problems of urban slums stem from a double burden—the burden of health problems associated with low incomes and under-development and the other burden placed upon society by industrialization. The former arises from the microbiological contamination of the environment and the latter from microchemical pollution of the environment. Thus, in urban slums, we see manifestations of these two burdens interacting with one another.

One-third of the urban population is not covered by drinking water supply, only 8 per cent of cities have underground sewers and 27 per cent had access to sanitation facilities in 1981. Ninety-one per cent of the slums have no separate latrines for households. The underground sewer system does not even cover nearly 77 per cent of the households in slums.

Demographic urban growth stimulates demand for resources, intensifies their utilisation and creates an unbearable pressure on the urban infrastructure and environment leading to precarious socio-economic conditions of living impeding the achievement of health by the people.

VULNERABILITY OF WOMEN AND CHILDREN

The brunt of slum life falls upon children and women. Apart from higher frequency rates of diarrhoeal disease, respiratory infections and malnutrition, there are problems such as child labour, child abuse, little or no access to learning opportunities, no informal education at home, cultural deprivation and lack of sensory stimulation. With the early life of the child spent in a dull and drab environment, it is most damaging to the social development of the child. The ecological deprivation apart from biological problems is the greatest threat to the optimal growth and development of the urban slum child. The health problems of urban slums could be described as an amalgam of problems related to poverty and under-development which one could call as deficiencies and hazards, problems related to urban environmental pollution, traffic accidents and the diseases that are associated with a modern stressful life.

Around 13 million children live in slum areas of which 3.6 million are under four years of age. Twenty-nine per cent of infant deaths and 22 per cent of child deaths in urban areas occur without professional medical attention. Twenty-seven per cent of urban children between five and nine years of age do not attend schools. The number in the slum areas must be higher, perhaps double. Sixty per cent of children below three years, 45 per cent between three and five years suffer from iron deficiency anaemia. And so the unhappy story goes on.

COMMUNICABLE DISEASES IN URBAN AREAS

Unplanned urbanization and disorderly growth of urban settlements have led to the creation of conditions conducive to the proliferation of insect vectors of disease. Large water bodies are left behind at many places as a result of road construction, housing construction etc. These are man-made problems that have led to urban malaria, urban filariasis and urban dengue. Fifty per cent of malaria in Tamil Nadu is contributed by Madras city alone, largely by uncovered overhead tanks and wells. Dengue which was a sporadic disease in our country is now an urban disease with periodical outbreaks and this is clearly the result of the urbanization process. The cities of Patna, Kanpur and Guwahati which until 1940 were free from filariasis are now endemic for this disease. Areas around Lucknow which were non-endemic up to 1950 are now endemic. Filariasis today is a spreading disease exposing 300 million people in the country to risk of infection. The most abounding mosquito in urban areas is culex fatigans carrying filariasis. The occurrence of vector borne disease is a hallmark of the urban phenomenon today.

Tuberculosis is classically a disease of overcrowding and poor ventilation and a high frequency of this disease is found in urban settlements in the slum areas. Not only is the incidence high, there is an early onset of the disease. Forty per cent of urban households live in just one room; this proportion is 70 per cent in Calcutta and 82 per cent in Bombay. The Urban Housing backlog rose from 2.9 million dwelling units in 1971 to 4.8 million in 1981 and may go up to 7.2 million by 1991.

Approaches to the Urban Crisis

A COMPREHENSIVE POLICY

Any rational approach to tackle a phenomenon of such magnitude and complexity will have to be comprehensive and founded on a reliable and objective information base in which appropriate indicators of the various components of the urban phenomenon are used. This is a neglected field to which we need to pay attention. The urban phenomenon is a multifaceted one. Social instability, cultural isolation, family disruption, drugs and alcohol, violence and crime, prostitution, child labour, female degradation and exploitation are some of the facets of the phenomenon. A variety of policy alternatives and organizational arrangements is needed to cope with it. A mix of approaches consisting of several elements—direct government provision of services, subsidizing in order to lower the cost of products and services, self-help and self-improvement policies, policies that promote public-private cooperation and strengthening the local urban government. We need cross-optimization of sectoral, inter-sectoral and territorial sub-systems and vertical coordination between multi-levels of Government.

HEALTH CARE—BASIC URBAN SERVICES PROGRAMME

In so far as the health problems are concerned it has been rightly stated that urban health care should be structured along the principles of Primary Health Care. This would imply the implementation of a set of health actions, related social actions and intersectoral actions. Involvement of the people becomes a critical element. The Government of India with the State Governments and UNICEF launched a new programme this year (1986) called the *Urban Basic Services Programme*. This is meant to improve and upgrade the quality of life of the urban poor, more particularly women and children, to enhance the survival and development of children and women of the urban low income areas by extending child care and health services, water and sanitation facilities, learning opportunities for children out of school and income generation opportunity for women. It focuses on immunization, infant feeding, home-based diarrhoea management, nutrition, education, child growth monitoring, responsible parenthood and birth spacing, functional literacy for women and income-skills learning by women. To structure such a programme, information relating to local needs and resources is a basic necessity.

This should include population distribution and migration trends, industry location, health status, city typology, utilization of health facilities, education, income, etc. Intersectoral action to provide water supply and sanitation, community education to promote hygienic practices and institutional support are key elements in improvement of urban health.

Role of Metropolitan Hospitals

One point that I would like to stress is the necessity for the large metropolitan hospitals to change their outlooks and to redefine their roles in the health care of urban populations. The hospital constitutes a key element in our health care system, and we have built a large number of them in our metropolitan areas. This, from one point of view, could be regarded as a strength to be harnessed to provide support to urban Primary Health Centres. They need to change from disease places to symbols of health with close linkages to community structures. Such hospitals should have Departments of Community Health to mobilize interest, expertise and direct interaction with the clinical services on the one side and with the communities in their catchment areas on the other. The Hospitals should provide support to the training of health workers and continuing education of health professionals. It is high time that a system of regionalized health care and graded referrals is introduced in urban settings in place of the present *laissez faire* in urban health. Community organizations should be established to promote self-reliance. Health services research is needed to find ways of promoting multisectoral policies and plants, of eliciting intersectoral coordination, utilization of services in the existing health care systems, the health care needs of the urban poor and patterns of community involvement. It is here that the leaders of the medical profession, biomedical specialists, deployers of hardware medicine who enjoy great prestige and status in society can play an important role by being the champions of change in the Metropolitan Hospital system. When such a change is brought about it will be easier to bring the fruits of modern advances in medicine to the urban slum populations and to rural communities. In this way we can apply the tools for monitoring, simple methods to quantitate disease burden in the community and even provide the basis for predictive medicine. The opportunities are immense. We must not blame high technology or low technology but must engage ourselves in the application of a technology that is safe and scientifically sound and is accessible to the urban slums. This will also tackle one of the major problems of the health care system in our country, namely the bypassing peripheral health facilities. If those facilities are strengthened starting with the home as a basic unit and the family as a biosocial unit and the community as a social support system and these are linked to hospitals in a spirit of support and sympathy, a great transformation in health care will take place and squatter ridden areas will then receive a measure of health care. We need to bring about a social reorientation of our hospital system and to link it with community-based health care facilities.

Municipal Health Departments

There have to be radical changes in the Municipal and Urban Health Departments. These have to be given a scientific foundation by locating in them trained, specialised physicians who have an understanding of the urban high density slum health problems. Strengthening these health Departments and improving the capability of the professionals working in them are necessary.

Public Health Engineering

Public Health Engineering is crucial if urban health problems are to be solved. It is a reflection on our sense of priorities that 'minor' public health engineering is languishing today while we demonstrate our ability to undertake great engineering constructions. Minor public health engineering is the single most important approach to urban health. But much can be done by coordinated action between the agencies responsible for different services. We have enough strengths to improve the health of urban slums. The urban upgrading programme initiated in collaboration with the University of Adis Ababa in Ethiopia with emphasis on mothers and children in the most deprived urban districts of the city, the five year programme for low income communities emphasizing environmental improvement for community development launched in Colombo, our own project in Hyderabad, the projects in Equador, Kaula Lampur, Lima and Rio de Janiero, are examples. The Hyderabad project involves a policy shift from *slum eradication to slum improvement*. In some projects active participation of the community has been secured. There is thus a variety of community experience where the programmes include components of health, family planning and environmental improvement. The problems of population growth and urbanization are interlinked in India.

There is need for a well-trained committed group of specialist physicians to look after the problems of urban health. The monitoring of environmental hazards and surveillance of ecological imbalances consequent upon urbanization and industrialization require the efforts of experts belonging to a wide range of disciplines. The urban health authority should be able to bring about coordinated action between various sectors, disciplines and institutions. Environmental pollution in the form of atmospheric pollution, water and food hazards need constant monitoring and the universities and Institutes of Applied Research have a key role to play in this. The weaknesses in these respects at present are well known. The urban people generally have an attitude of apathy towards Municipal institutions whose base is being eroded. There is a general trend towards de-municipalization of sources of income or basis of revenues. A systematic Urban Basic Services Programme with the urban poor as the target beneficiaries needs to be pursued with the greatest urgency. The programme should coordinate the work of different agencies connected with the provision of basic services such as water supply, sanitation, nutrition, health, education, employment and shelter and build bridges between community groups and Government agencies. The *minimum actions* under this Programme fall under Physical Services and Social Services; physical including water, human waste disposal, garbage collection and disposal and fire protection, social including health care, Maternal and Child Care, Recreation and Education.

Urban Policy

A scheme for environmental improvement of slums is one of the points in the 20-Point programme which forms the Charter for the Socio-economic Development of the country. What are the policy pegs on which to hang a strategy and develop a programme? In the formulation of urban policy, one has to take into account population distribution, industry location, migration.

Only a comprehensive approach can bring lasting solutions. Spatial interaction and interflow of resources between rural and urban sectors should be done to ensure balanced development of the country as a whole. There should be greater emphasis on community organization and the strengthening of the health care component in all the plans for urban improvement. The present policy of India, rightly so, is to provide investments in the environmental improvement of slums rather than massive relocation. We now know that demolition without replacement is a futile exercise. The sites and services scheme through which provision of community infrastructure like electricity, water, sanitation, school and health care centres are made seems to be an alternative worth pursuing.

Conclusion

This is a time of challenge and a time for justice. Rapid urbanization and attempts at rapid economic growth without commensurate investment in social services and infrastructure is the cause of the present urban dilemma. The paradox is that it is in the urban areas where the majority of the doctors live, advanced care institutions are located, communication and transport services are better developed. The gulf between demand and supply service is widening. The service delivery model, the top-down approach, has not proved to be very effective. An alternative is to mobilise people's interest and resources to improve urban living environments and develop participatory urban services with subsidization by government. Experimental approaches to delivery of Basic Services have been developed in five countries of Asia recently namely, Indonesia, South Korea, Malaysia, Philippines and Hong Kong. As a result of these studies, policy priorities have been identified for government and for the urban communities (Yue-Man Yeung, 1985). For Government to respond, information on urban service needs, flexibility in urban delivery systems, training of community leaders and administrators, understanding the existing community resources and willingness to involve a wide spectrum of community resources and coordination of institutional responses are identified. For urban communities to participate, communication of their needs to Government, development of participatory activities and creation of community awareness have been suggested. Essentially, an ecological and epidemiological approach to health development is needed for improving health in the urban slums.

REFERENCES

Yue-Man Yeung, *Provision of Urban Services in Asia: The Role of People-based Mechanisms*. UN Centre for Regional Development, Nagoya, Japan, 1985.

18

Nutrition and Brain

P.N. Tandon

Malnutrition and undernutrition continues to be a major socio-economic problem in our country as also in most of the developing world. Some of the "cold" but mind boggling statistics from the nutritional surveys are a poignant reminder of the magnitude of this human problem. Out of a child population of approximately 225 million, in our country, nearly 100 million children belong to the category of the deprived, 60 million of whom are estimated to be malnourished (Nutrition News 1981). A glance at some of the nutrition maps of India (Gopalan and Raghavan, 1971) reveals that varying grades of protein-caloric malnutrition in children is seen all over India. Besides this, there are large areas of the country where other types of nutritional disorders like pellagra, lathyrism, iodine deficiency and fluorosis etc. are endemic.

A large mass of information has accumulated over the years, which unequivocally demonstrates that severe malnutrition, specially during early life, the period of active growth of the brain, prevents its optimal development. The social implications of such a phenomenon, are scaring when the numbers involved are of the order mentioned above. The obvious question is, 'Are we heading for a vicious circle, wherein the existing socio-economic environment would prevent a large section of our society from fully achieving its intellectual (and physical) potentials, which in turn would further deteriorate the environment'? I am, therefore, sure that you would appreciate the reason for my choosing this subject for this evenings talk rather than presenting before you some of our work and studies in neurosurgery, my special field.

To start with let me present a few general facts regarding the brain as some of you in the audience, belonging to diverse disciplines, may not be familiar with. The basic functional unit of the brain is a neuron or a nerve cell, which has its processes—the axons and the dendrites—through which it transmits and receives messages from other neurons. The point of contact between the two neurons is called a synapse. Made up of many billion nerve cell units, interconnected by many million connecting nerve threads, weaving incredibly intricate patterns, the brain controls our activity and behaviour and is responsible for our sensations and sensibilities. For the proper functioning of the brain, there should be timely and sequential growth of neurons during the critical period of its development. This should lead to development of proper connections between neurons and modification of the connections according to the peripheral input.

The period of maximum growth and development of the brain is during later part of the foetal life and first two years after birth. There does not appear to be any significant proliferation of neurons after this age. However, the growth of new processes, their insulation (myelination) and connections continue beyond this age.

Numerous data in the literature based on animal experiments and observations in humans, confirm that severe malnutrition in early life delays brain development (Tandon and Gopinath, 1984). It may, however, be mentioned that while the growth of the body is adversely affected as a result of maternal malnutrition, as a rule brain development is not affected adversely. The foetus is spared at the expense of the mother (Balazy et al., 1979). Severe malnutrition during gestation results in abortion and still birth. The situation is different if nutritional deficiency (protein-caloric malnutrition) in postnatal period results not only in reduced body weight but also reduced brain weight. The most vulnerable period for the brain is, thus, the immediate postnatal period and early childhood. A large number of human and experimental studies have established that nutritional deprivation during the period of rapid growth results in reduced size of the head, reduced weight of the brain, diminished number of neurons, alteration in the pattern of dendritic arborization and spines and reduced density of synapses. There is also a large volume of literature now available which unequivocally demonstrates that besides the morphological changes there are concomitant biochemical alterations also. These studies, both from India and other parts of the world have been summarized by us in a monograph published by the Indian National Science Academy and will, therefore, not be described in detail here.

Two important points, however, need some discussion. It is an accepted fact that within a very wide range neither the size of the head or the weight of the brain are statistically correlated with intelligence or learning abilities. There is a general agreement that the observed morphological and biochemical changes cannot automatically be accepted to imply that these determine the intellectual function of the individual. Let us briefly consider what can affect intelligence and learning capabilities. These factors are: (1) genes or heredity—which determines the basic pattern of growth, (2) nutrition, (3) socio-economic background, and (4) early experiences or environmental stimuli. Enough evidence has already accumulated to suggest that nutritional deprivation cannot be the only or even the most important factor responsible for poor intellectual functions or learning capabilities. The clustering of economic, social and interpersonal interaction variables are important factors. This has repeatedly been observed in studies carried out in widely differing socio-economic and ethnic groups. An interesting observation by Srikantia and Sashtri (1971) is worth quoting, "Children suffering from malnutrition have mothers who are less intelligent, less resourceful and more ignorant. These maternal attributes influence the mental development of the child independent of its nutritional status". Cravioto and Deticardie (1978) echoed the same sentiment in their study and concluded that when parental stimulation and interaction were high, even a malnourished child performed well. Some investigators have gone to the extent of stating that psychological deficit is due mainly to factors other than nutritional ones, that is the socio-cultural factors.

The second important point is the reversibility of the morphological, biochemical and behavioural effects of malnutrition. While a few workers felt that the damage is permanent, enough evidence, both in human and experimental animals, has accumulated to demonstrate that timely rehabilitation can reverse these changes. Thus, Kagan concluded that if malnutrition is corrected "in time, all its adverse effects on the brain are reversible. You may be late but you can get there". Evans et al. (1971) in a 10 years follow up study of 40 children hospitalized for Kwashiorkor found no difference between the patients and their siblings in intelligence test performance. However, once again the role of socio-economic parameters acquires a great significance. Correction of the nutritional deficiency is not enough to achieve the desired psycho-social levels of behaviour. Irwin and Klein (1979) clearly demonstrated that while nutritional correction alone failed to improve the learning capabilities, when it was supplemented by cultural support, the results were far superior. Anandalakshmy (1980) demonstrated that irrespective of the nutritional status maternal affiliation and cognitive stimulation have positive effects on the development of the infants. These observations are of great importance in planning rehabilitational programmes for such children.

Iodine Deficiency and Brain Development

While a large volume of information has accumulated in respect of protein-caloric malnutrition, there has been relatively very little information gathered regarding deficiency of individual components of diet like various minerals and trace metals. However, deficiency of one such substance, iodine, has already acquired staggering dimensions in large areas of our country. It has been estimated that approximately 120 million persons live in iodine deficiency regions, specially in the hills and "*terai*" areas in the northern part of country. It is not as commonly recognized that other inland areas including Delhi qualify to be included as endemic zones. Out of these 120 million people nearly one in three has goitre, but even more important is the recent finding that 60 per cent of the patients are functionally hypothyroid. Hypothyroidism adversely affects brain development, during the period of active brain growth. A series of epidemiological, clinical and laboratory studies carried out by one of our colleagues Dr. Kochupillai and his associates have revealed that cretinism, mental subnormality, deaf-mutism and other neurological deficits are widely prevalent in the sub-Himalayan terai areas (Kochupillai et al., 1973, 1980, 1982, 1984). Utilizing highly sophisticated and sensitive techniques, they have recently demonstrated that neonatal hypothyroidism is found in 4 to 15 per cent of infants investigated from iodine deficient areas as compared to an incidence of only 0.1 per cent of control population from non-deficient areas. A number of experimental studies have already unequivocally demonstrated that hypothyroidism during intra uterine and immediate postnatal period leads to irreversible brain damage affecting the maturing neurons, their dendritic arborization, chemotransmitters and receptors resulting in mental retardation (Eayrs, 1971; Brasel and Boyd, 1975; Patel et al., 1980). It is a matter of grave national shame that in spite of decades of a national programme to eradicate this easily correctable deficiency, the problem appears to be getting worse rather than improving. Effect of Alcoholism on the Brain—while the brain of an infant is susceptible to a variety of nutritional deficiencies, the adult brain fortunately is not as vulnerable. However, there is increasing evidence to suggest that nutritional deficiency secondary to alcohol abuse results in demonstrable brain damage even in adults. It may be clarified at the outset that on the basis of the available evidence, this occurs as a result of nutritional primarily thiamine deficiency, rather than as a direct toxic effect of the alcohol itself. Secondly such damage is related to excessive use of alcohol and has not been observed among casual social drinkers. In its most severe form. the characteristic lesion affects the upper part of the brain stem and the region of the mammilary bodies, resulting in the so called Wernicke's encephalopathy and Korsakov psychosis. This is clinically reflected as gross disturbance of memory, specially loss of recent memory, disturbance of sensorium resulting in stupor or coma and abnormalities of ocular movements. Similarly it has been known for many years that chronic alcohol abuse results in permanent loss of Purkkje cells of the cerebellum, clinically manifested as disturbance of equilibrium, gait and motor coordination. Progressive deterioration of intellectual function has long been observed amongst chronic alcoholics. However, till recently it has been difficult to demonstrate actual loss of cortical neurons. With the advent of CT scan it has been possible to visualize the human brain *in vivo*. A number of studies utilizing this investigation have unequivocally demonstrated significant cerebral atrophy in chronic alcoholics. An interesting observation of some practical importance is that in the early stages, the

CT findings of 'atrophy' are reversible, if alcohol abuse is stopped and nutritional deficiency corrected.

From this presentation it will be obvious that nutritional damage to the brain, affecting large proportions of our population, is a matter of grave concern. Fortunately most of it is preventable provided timely steps are taken. The very magnitude of the problem in terms of number involved and the seriousness of the damage to the most precious possession of man, makes it imperative for us to make concerted efforts to overcome this national shame. Let me conclude by a quotation from my teacher Dr. Wilder Penfield:

> "Men ought to know that from the brain and brain only arise our pleasures, joys, laughter and tears, through it particularly we think, see, hear and distinguish the ugly from the beautiful, the bad from the good........
> ....To consciousness the brain is the messenger. The brain is the interpreter of consciousness"

So let us try and make it possible for all for whom we are responsible to achieve all its potential.

REFERENCES

Anandalakshmy, S. Paper presented at Indo-US Seminar on Deprivation, its effects on early learning. New Delhi, May 1980.

Balazy, R., P.D. Lewis and A.J. Patel. In *Human Growth* Vol. 3, (Eds.) Falkner and J.M. Tanner, Plenum Publishing Corporation, pp. 415–480, 1979.

Brasel, J.A. and B. Boyd. In *Perinatal Physiology and Disease.* (Eds.) D.A. Fisher and G.N. Borrow, Raven Press, New York, pp. 59–71, 1975.

Cravioto, J. and E.R. Deticardie. In *Perceptual and Learning Disabilities in Children.* (Eds.) W.M. Cruickshank and D.P. Hallatian, Syracuse University Press, p. 263, 1978.

Eayrs, J.T. In *Hormones and Development* (Eds.) M. Hamburgh and E.J.W. Barrington, Appleton Century Crafts, New York, 345–355, 1971.

Gopalan, C. and K.Y. Raghavan. *Nutrition Atlas of India,* National Institute of Nutrition JCMR: 1971.

Irwin, M.H. and E. Klein. In *Behavioural Effect of Energy and Protein Deficits,* (Ed.) J. Brozek, Belkesda NIH publication 779, p. 239, 1906.

Kochupillai, N., M.G. Karmarkar, D. Weightmann, et al. *Lancet* (i) 1021, 1973.

Kochupillai, N., V. Ramalingaswami and B. John. Wiley Medical Publication John Wiley & Sons, New York, pp. 101-121, 1980.

Kochupillai, N. and C.S. Pandav, *Future* 23, 1982.

Kochupillai, N. In *Nutrition and Brain.* (Eds.) P.N. Tandon and G. Gopinath, INSA, pp. 83–88, 1984.

Patel, A.J. et al. *Brain Research 198*, 389–402, 1980.

Srikantia, S.G. et al. *Proc. Nutrition Soc.* India 10, 1971.

Tandon, P.N. and G. Gopinath. *Nutrition and Brain,* Status Report Series 1. Golden Jubilee Publication Indian National Science Academy, New Delhi, 1984.

19

Environmental Factors Affecting Human Work Performance

J. Sen Gupta

The subject of this paper pertains to the many investigations carried out by Defence Institute of Physiology in the field of Environmental Physiology, which is the major area as far as Defence Research in Physiology is concerned. It is a coincidence, that the focal theme of the 73rd Session of ISCA is 'Environment'.

From the prehistoric days, man has had to work for his food, survival and existence in any environment whether it is in the Arctic cold or in the dry desert or tropical heat. Man, has to put in physical effort for his living, either by hunting, tilling lands, toiling in the shop floor of modern industrial complexes, in underground mining operations, or in defending the country in extreme hostile environments.

Environmental Heat Affecting Performance

Environmental physiology is emerging as an important branch of the science of physiology. It is the branch concerned with the physiologic responses of the healthy man to environmental change. It focuses on the environment-organism interactions of environmental stimulus with biologic system that produces a physiologic response. An environmental system contains a set of elements and are of three kinds in general i.e. matter, energy and force fields.

Man is a tropical homeotherm, who without the protection of clothing and shelter cannot tolerate cold climates as do many birds and fur-bearing mammals. On the other hand, with an adequate supply of drinking water and proper clothing to protect his skin from the damaging ultraviolet radiation of the sun, man can live and work in the hot dry desert environments, where his total heat gain by convection and by radiation from the sun and ground may far exceed his resting metabolic heat production. To maintain a constant body temperature, an organism must balance its rate of heat dissipation against its rate of heat gain. Heat is added to the body by metabolism, which in work increases as the work rate increases. In hot environments, the body gains heat by radiation, convection and/or conduction, depending on the respective temperature gradients between the skin and the environment. Heat is dissipated from the body by evaporation of water from the skin and the respiratory air passages in the hot climate, whereas, in the cold environment it is dissipated by radiation, convection and conduction. The balance of the heat exchange between man and his environment is expressed by the combination.

$$M \pm R \pm C \pm K - E \pm W \pm S = 0$$

where each term is expressed in $\text{Kcal} \times \text{m}^{-2} \times \text{hr}^{-1}$

M = Metabolic rate of the man
R = Radiation
C = Convection
K = Conductive heat exchange
E = Evaporative heat exchange
S = Stored heat
W = Work

The strain shown by men exposed to the stress of hot environment is indicated by increased heart rate, sweating, skin temperature and core temperature. Adjustment of continuous blood flow and evaporation of sweat from the skin represent the first and principal lines of the body's physiologic defence against overheating during prolonged exposure to hot environments and/or during work with increased metabolic heat production. The capacity of these mechanisms to balance heat dissipation with heat gain is remarkably great. However, even within the range of combined environmental and metabolic heat loads that can be dissipated by these mechanisms, changes in body temperature do occur.

Temperature regulation during work in heat remained an interesting topic since 1938. It was demonstrated (Nielsen, 1938) that over a 60 minute period of exercise, rectal temperature rose to a new steady level and was directly related to metabolic rate and was unaffected by air temperature over a wide range of temperature of 5–30°C. However, it has been observed (Lind, 1963; Robinson, 1963; Wyndhan et al., 1979) that the relationship between rectal temperature and metabolic rate holds true only up to certain critical air temperature which are different for different metabolic rates. The higher the metabolic rate, the lower is the critical temperature. Our studies (Sengupta et al., 1979) on acclimatized Indian subjects also support this contention. It has been further observed that during work in high ambient heat, rectal temperature continues to rise leading to incapacitation or termination of work.

Metabolic cost of work in hot dry and hot humid climates was extensively studied (Dimri et al. 1980; Sen Gupta et al. 1977). A significant fall in aerobic oxygen consumption during sub-maximal work has been observed. This fall in steady state oxygen consumption was found to be highly correlated with increase in heat stress from comfortable temperature to very hot humid environments. The anaerobic oxygen supply on the other hand, has been found to be increasing significantly. The increase in anaerobic component during work in heat was further confirmed by the increase in lactic acid accumulation in blood, the increase being significant at each sub-maximum work loads. The finding is in conformity with previous workers (Dill et al. 1931; Williams et al. 1962) who also observed higher lactate accumulation during work in heat. Along with decrease in aerobic O_2 supply and increase in anaerobic O_2 fraction during work in heat, the total oxygen cost of the work, increases in hot environments than in a comfortable atmosphere. This shift in aerobic-anaerobic ratio is possible due to diversion of a large amount of blood from the working muscle to the skin for thermoregulation. A diversion of 2.0 l/min of blood to the skin can lead to approximate reduction in oxygen uptake by 200–300 ml/min during work, if arterio-venous oxygen difference remains constant (Ramaswami et al. 1970). During a maximal efforts of a few minutes duration, in a hot dry and humid environments, it was observed that maximal oxygen uptake capacity (VO_2 max) decreased significantly with the increase in thermal stress and also indicated greater deterioration in a hot humid climate than in a hot dry climate (equivalent effective temperature), yielding a very significant relationship with the wet bulb temperature (Sen Gupta et al. 1977). The deterioration in the physical work capacity in terms of VO_2 max has also been correlated with other heat stress indices (Swamy et al. 1978). Similarly, results from the studies in natural environment in the summer and winter also confirmed (Sen Gupta and Malhotra, 1979) these findings.

Assessment of Work Capacity

The problem of assessment of an individual's capacity for prolonged continuous work from physiological measurements is quite complex and is further complicated when work is performed in hot environments. However, several indices have been proposed by various workers (Bink, 1962; Benjer, 1962; Idem, 1968; Michael et al., 1961; Müeller, 1950; Idem, 1962). The limitation of these studies have been pointed out (Costill, 1967; Idem, 1972; Sen Gupta et al., 1979).

Thus there appears to be little agreement among various workers regarding the work load recommended for different work-rest schedules. As reported earlier (Sen Gupta et al., 1972) exercise dyspnoea gives a good indication of a person's endurance capacity for different work rates. In another study, we have shown (Sen Gupta et al. 1974) that an index based on cardio-pulmonary strains imposed by work, yielded a highly significant relationship with the endurance time in work. The method was considered to be very useful for the prediction of work tolerance. Another alternative approach was also proposed (Sen Gupta et al. 1979) based on aerobic-anaerobic fraction of O_2 supply during work, and this has been found to be quite satisfactory.

Assessment of Endurance Work in Heat

In one of our recent studies (Sen Gupta et al. 1984) we have observed that the duration in continuous physical efforts in different rates of activity decreased significantly with an increase in thermal stress. During progression of the work, the mean skin temperature decreased in a hot dry climate whereas it increased in hot humid environment. The mean rectal temperature increased in both the dry and humid heat but the rate of rise was much faster in the hot humid environment than in hot dry environment and attained the critical target temperature much earlier. It was also observed, that the heart rate response was significantly higher in the hot environment than in the comfortable climate for the same work load. However, the rate of increase in the heart rate towards the target maximum of 180 beats/min was much faster in hot humid than in hot dry environments. For regulation of thermal load on the body, sweating is the principal mechanism of heat dissipation, particularly during work in heat. On comparison of the sweating rate during work in hot dry and humid environment, it was observed that the rate of sweating is comparatively less in dry conditions than in humid ones. The possible reason for this difference may be in the efficiency of cooling. Thus, the rate of sweating as well as efficiency in evaporative cooling are important criteria in heat regulation.

From these findings, it appeared that it would be desirable to combine a number of functional aspects into a single physiological index to predict the tolerance of work by man in hot dry and humid conditions. Safe tolerance time during work in heat has been proposed by different workers (Gagge et al. 1941; Lind et al. 1967). However, for an useful universal index, many other influencing factors like acclimatization, nutrition, dehydration status, age, sex and state of physical fitness should be considered.

Man in Cold Environment

From time immemorial, man has explored the coldest regions of the earth and can live in the Arctic and Semiarctic regions. The eskimo, the Arctic Indian and the Lapp have long been symbols of man's ability to live at low temperature, which drop to −40°C for long periods with extremes as low as −68°C.

Exposure to cold is characterized by air velocity and the radiant environment, and is modified by clothing or shelter. It is a negative heat load. Heat loss to environment H is expressed (Gagge et al. 1941) by the following equation:

$$H = K_0 (T_s - T_a)$$

T_s = average skin temperature.

T_a = air temperature, qualified according to air movement.

K_0 = (Hr + ha) heat transfer coefficients for radiation and convection.

The human body loses heat to its surrounding by several physical processes. By convection heat is transferred directly to the surrounding air by movement of air. At high altitude, during the day, body gains heat by the process of absorbing solar radiation, which is pronounced in the clear sky and is exaggerated by reflecting radiation from snow. Conduction of heat from the body follows direct contact with the surroundings. Each of these methods of heat loss carries implications for the implementation of simple precautions in those exposed to severe cold. Loss of heat by convection is restricted by diminishing the area of skin exposed to the surrounding air, by the evidence of exposure to wind which destroys the still insulating layer of warm air around the body, and by avoiding the bellow effect of clothing loosely fitting around the neck, which may force out the warm insulating air. Avoidance of direct contact of the body with snow or metallic components or vehicles or guns will cut down heat loss by conduction. So also by keeping the extremities dry, heat loss can be minimized, for water is a good conductor of heat and wet clothes lose their power of insulation. Furthermore, wet clothes require much heat to evaporate their water and this is drawn from the body. Man's immediate response to cold is to conserve heat by reducing the rate of blood flow to the skin with some èrection of hairs to give increased insulation. The skin temperature falls, and prolonged exposure to cold demands higher rate of heat production. Cold sensitive receptors in the skin and viscera send stimuli to the thermostatic centre in the hypothalamus.

This stimulates motor centre for shivering located in the hypothalamus, which in turn causes increased skeletal muscle tone and then shivering (Ward, 1975). This coordinated movement of voluntary muscle under involuntary nervous control may increase heat production three to four fold. In case the shivering mechanism fails to maintain body thermostat then hypothermia sets in. This process is said to begin when the body temperature falls below 35°C. It becomes lethal when the temperature of the vital organs fall to about 24°C. Due to impairment of the central nervous function, there is a vital detrimental effect on the heart and ultimately death may result due to cardiac arrest. There is a slowing of the heart rate until the cardiac pacemaker fails. Ectopic beats or ventricular fibrillation may supervene. These alterations in the cardiac rhythm are probably related to myocardial ischaemia. In addition, when haemoglobin is cooled, it releases oxygen less easily. When these effects are added to impaired coronary blood flow, the supply to the cardiac muscle is barely sufficient for its needs even at rest. Besides, the general body cooling, there could be local effects manifested in the form of cold injuries, the effect may be local. Under dry freezing conditions frostbite may ensue.

The immediate effect of cold exposure that has adverse consequences for the performance of physical work is bronchospasm. However, this seem to be a transient phenomenon. Inhalation of large quantities of arctic air during vigorous work have permanent effects upon the cardio-respiratory functions (Rode and Shepherd, 1971). Exercise ECG during heavy work on Igloolik Eskimos indicated a right bundle branch block (Shepherd, 1975), and in many instances enlargement of the main pulmonary artery (Hildes et al. 1976). Acute exposure to mild cold, however, can induce small improvements in the working capacity (Mathew and Sen Gupta 1982), possibly through an increase in tone of venous reservoirs and a redistribution of cardiac output from skin to active muscles. However, there is little evidence that cold in itself has any long-term effect upon physical fitness (Anderson, 1967). The maximal aerobic power of some of the active Igloolik Eskimos and Kautokeino Lapps is higher than in many of the tropical communities (Bink, 1962). These people have a better cardio-respiratory function than white service volunteers. The main factor responsible for the difference seems to be a higher level of physical activity rather than cold exposure *per se*, as even within Igloolik, sedentary Eskimos have poorer aerobic power than the active hunters and more highly acculturated groups such as the Alaskan Eskimos who have quite low maximum oxygen intakes (Rennie et al. 1970).

Working Capacity of Man at High Altitude

The unique physiological response on exposure to high altitude is hypoxia. Hypoxia is a state of the organism in which the rate of oxygen utilization by the cells is inadequate to supply all their energy requirements.

The lowered oxygen tension in high altitude environment in turn affects oxygen tension in the lung alveoli. Partial pressure of oxygen in the lung alveoli is always considerably less than that of the atmospheric air. At sea level this pressure is 102 mm Hg against 159 mm Hg in the atmospheric air (difference of 57 mm Hg). The gap between these two pressures become less marked with altitude due to increase in pulmonary ventilation. The fall in oxygen tension in the lung alveoli with altitude affects the quantity of oxygen carried by the blood from the lungs to the tissue of the body. This is because most of the oxygen (98 per cent) which is carried out in the blood is in loose combination with haemoglobin. The combination of oxygen with haemoglobin depends upon many factors like partial pressure of oxygen in the lung alveoli, pH and temperature of blood. Haemoglobin is about 100 per cent saturated when the oxygen tension in the alveoli varies between 80 and 100 mm Hg. At an altitude of 2720 m, when the oxygen tension in the lungs is about 65 mm Hg, haemoglobin is only 95 per cent saturated. The resultant 5 per cent deficiency is not felt appreciably by the body for normal resting life but it has considerable effect on any strenuous work and in competitive sports. At higher altitudes, the oxygen saturation of haemoglobin falls steeply with the result, the amount of oxygen carried by the blood shows a corresponding decline and becomes short of the requirements even for less strenuous activities and symptoms of hypoxaemia appear. With progressive acclimatization and continuous stay at these altitudes, there is some improvement in O_2 carried in the blood but even then remains much below the sea- level capacity.

Because of the lowering of arterial oxygen saturation and possibly due to limitation in cardiac functions, maximum oxygen consumption in sea level subjects on induction to high altitude falls with barometric pressure (Pugh, 1958; Idem, 1964). Maximum oxygen uptake capacity (VO_2 max) in human beings has been considered as a best single index for assessing physical work capacity (Γeyler et al. 1943). A progressive fall in physical work capacity, as reflected by decrease in VO_2 max, with increase in altitude has been reported by many workers (Dua et al. 1966; Malhotra et al. 1969; Balkae, 1964; Dill et al. 1964). The fall is more marked during acute induction to altitude or during the first few days of arrival at altitude. However, on chronic exposure to altitude, deterioration in VO_2 max is insignificant at 1500 m, amounting to only 2 per cent but at higher altitudes the fall is significant. In one of our studies (Malhotra and Sen Gupta, 1976), we have observed a drop of 10 per cent at 3500 m, 25 per cent at 400 m and 50 per cent at 6000 m. Along with the decrease in maximal aerobic power deterioration in endurance running at constant speed and stepping up and down a 37.5 cm high stool has been observed in acclimatized low landers at different altitudes (Ramaswami, 1966). Subjects were made to run to exhaustion at three different speeds at 10 (Dill et al. 1964) and 15 km/h first at sea level and subsequently at altitudes of 2270 and 4000 m. Results indicated that endurance for all of these speeds reduced considerably. Similarly Pugh et al. (1964) reported that the rate of climbing and height climbed per day decreased significantly in Everest climbers.

However, changes in muscular power of man of arm and shoulder muscles, abdominal and trunk muscles as measured in field tests up to an altitude of 4000 m did not indicate any significant change (Malhotra et al. 1969). Performance scores were almost the same. This is in agreement with the other findings (Christensen and Nielsen, 1936; Hollman and Venrath, 1966).

Athletic Performance at Altitude

In October 1963, the International Olympic Committee chose Mexico city situated at an altitude of 2380 m as the venue for the 19th Olympiad. Although many of the effects of high altitude on the human body were known at that time, it was not clear whether or not the comparatively moderate elevation of Mexico city would be deleterious to athletes coming from the sea level. The practical effects of high altitude on athletic performance can best be judged by studying the performance of the world record holders at sea level. In the final 10,000 m race, Ron Clarke, who was the world record holder in this event finished sixth and in a state of collapse. The first five places were filled by athletes either native to high altitude or who had lived there for a long time. Time of the winner (Temu, 29 min 27.4 sec) was almost two minutes slower than Clarke's world record. Performance in other events indicated a small gain, as in running events of 100 m to 400 m (possibly because of decrease in wind resistance) and slowing of time for long distance endurance events. This slowing amounted 6.7 per cent in the 5000 m and rose to 17–22 per cent in the marathon. Craig (1968) expressed the results as a percentage of the world record plotted against their duration. When a linear regression was applied to both track and swimming events, showed that although world records were extended in short events, there was a steady decline in events lasting longer than one minute. This fall ranged from 3 per cent at four minutes, to 8 per cent at one hour. Similar studies have been conducted by us (Ramaswami et al. 1970) on Indian athletes for selection for the Mexico Olympics at 1620 m and at 2220 m. The altitude of 1620 m exerted disadvantageous effects of the running events of over 1500 m and at 2220 m, running events of even lesser distances were likewise affected. The decline in running speed in 1.6 km race in healthy Indians at sea level and at altitudes of 2270 m, 3100 m, 3500 m and at 4000 m has been studied by us. It was seen that the maximum speed of 16.5 km/h at sea level was reduced to 14.2 km/h at an altitude of 2270 m and further reduced to 11.7 and 10.6 km/h at altitudes of 3500 m and 4000 m respectively.

Physical Performance at Great Heights

Pugh from his experiences in the Himalayas is of the opinion that 5790 m is too high for what he calls "complete adjustment". Similarly, native miners of Auconquiuha in the Andes live at 5330 m but they climb every day to work at 5790 m. They refused to occupy huts at working site on account of difficulty in sleeping. Because of these reasons heights above 5790 m are considered extreme altitude. Studies on Everest climbers (Pugh, 1958) showed that climbers maintain surprisingly high oxygen intakes up to about 6100 m. They accomplish this by working nearer to their capacity and for this reason the hours of climbing decline progressively from 10–14 hr in lesser altitudes to 5–6 hrs in these heights. At heights above 7600 m continuous progress is no longer possible and the climber has to adopt the device of working intermittently. On the higher slopes of Everest, it has been reported that climbers have to stop every twelve paces in order to rest and recover, Himalayan 'Sherpa' porters who carry loads exceeding half their body weight up to 6100 m use the same method, the periods being shorter and the rests longer as the height increases

(Pugh, 1958). Recent studies (West, 1983) on Everest climber's without oxygen demonstrated that the successful climbers had a VO_2 max of 1.051/min and they could sustain the slow pace of climbing at 8100 m.

High altitude native residents show a high tolerance to maximal exercise (Dua and Sen Gupta, 1980; Hurtado, 1956). This feature must have been acquired over few generations due to the development of anatomical and biochemical features at the tissue level enabling them to explore the environment of high altitude to its best advantage.

Work Performance by Man Underwater

India has vast undersea domain of continental shelf, containing a wealth of biologic and mineral resources. Without exploiting these resources, no country can prosper with its land resources only. Beyond conventional diving, it has been necessary to fabricate various types of undersea habitats and to devise new methods of locomotion for transfer of divers from submerged habitats to surface decompression chambers. Extensive commercial installations include underwater welding chambers for offshore oil exploration and pipeline construction. Pressurized tunneling in compressed air (up to 50 PSI) involves another type of environment required for construction facilities. These developments challenge both the physiological capability and engineering ingenuity. Primary physiologic problems involve the effects of temperature, humidity, compression, nitrogen narcosis, oxygen tolerance and toxicity, inadequate pulmonary ventilation and the complicated problem of safe decompression to normal sea level atmosphere. These aspects will be dealt with in detail by experts in the field later on.

At normal atmospheric pressure the amount of work a man can do, seems to be limited by his cardiovascular efficacy. At depth, however, alveolar ventilation may be the limiting factor. Increased air density may prohibitively increase flow resistance through a breathing apparatus. Even if a diver uses superior breathing apparatus, his maximum voluntary ventilation (MVV) decreases markedly with increasing depth (Lanphier, 1967). The principal factor that limits MVV is the conductance of airways.

During hyperbaric oxygenation, normal men respond to exercise with slower heart rate, decrease in cardiac output and increase in peripheral vascular resistance (Wholen et al. 1965). Decreased respiratory rate and increased tidal volume with no significant change in pulmonary ventilation during exercise at 2.02 atm has been reported (Salzano et al. 1967). They have further reported significantly higher O_2 consumption for similar submaximal exercise in hyperbaric environment. This increase in oxygen consumption may be due to the greater oxygen cost of breathing denser gases and moving the limbs in a denser environment. Increased arterial CO_2 tension at the end of the exercise has also been observed by several workers. This rise in PCO_2 may reflect a decreased ventilatory sensitivity to CO_2 in a hyperoxic setting (Lambertsen et al. 1959; Lloyd et al. 1958). The early occurrence of oxygen toxicity is well documented in individuals exposed to high oxygen tension who are working strenuously. The occurrence of hypercapnoea in subjects during exercise at elevated oxygen pressure should render them more vulnerable for developing toxicity. Development of oxygen toxicity would also suggest a decreased efficiency of energy production while maintaining an increased oxygen consumption. However, these difficulties have been eliminated by saturated diving with helium and oxygen in different proportion at various depths. Hamilton (1967) reported saturation diving to 650 ft of sea water and observed no appreciable change in oxygen consumption, and a slight rise was noticed in end expiratory CO_2. The ventilatory response to exercise was much reduced but the heart rate responded in a normal way. CO_2 response curves were shifted to the right but showed little change in slope. He concluded that man can spend long periods of time at the depth of the continental shelves and can perform moderate physical work there. Similarly Salzano et al. (1971) concluded from their studies at 1000 FSW that gas exchange in divers breathing 99.1 per cent He and 0.9 per cent O_2 during rest is essentially normal and that normal men can perform moderately heavy exercise similar to that at sea level. Impairment of the capacity to perform physical work could not be discerned by these authors. Similar conclusions were made (Miller et al. 1971) during heavy work at 1500 ft. Thus, to explore our long continental shelf for oil, gas, minerals and fish we have to tackle underwater physiological and medical problems in addition to equipment. Facilities in terms of technical personnel and infrastructure are to be developed to undertake researchers in this direction. In addition, to defend and protect our huge sea borders and submersibles, it is essential to equip the Indian Navy with modern ships. Research in underwater medicine is a must for an efficient man-machine integration system. It is therefore, high time that we in India divert our attention in this direction at the national level.

Environmental Pollution Affecting Human Working Capacity

A pollutant is an undesirable substance or agent that is present in the air, water or soil. A pollutant is also a foreign or extraneous substance, material or agent that impairs the quality or diminishes the life supporting capacity of an environment. They may occur as simple or complex substances, mixtures or aggregates. They may be in the air we breath, the food we consume and the water we use and drink.

The most significant air pollutants resulting from combustion of coal, oil, gasoline, natural gas and wood/cowdung cakes are carbon monoxide, sulphur oxides, hydro carbons and secondary photochemical oxidants.

Carbon monoxide combines avidly with haemoglobin faster than oxygen to form carboxyhaemoglobin in the red blood cells. Even low concentration of carbon monoxide effectively reduces the availability of haemoglobin to oxygen. As such, oxygen supply capacity to the working tissues is hampered resulting in reduced working capacity. The generally accepted threshold limit value for an eight hours per day exposure should not exceed 50 ppm. This inspired carbon monoxide concentration results in a carboxy haemoglobin equilibrium saturation of about 5 per cent above baseline values.

The bulk of sulphur oxides are derived from burning coal (60 per cent) industrial processes (22 per cent) and burning oil (4 per cent). Sulphur dioxide (SO_2) is the most abundant pollutant oxide of sulphur. It is largely produced in the burning of sulphur containing coal and oil. It is a pungent, irritating corrosive gas capable of producing significant acute and chronic bronchopulmonary reactions. Sulphur dioxide toxicity is influenced by climatic environment. Higher levels are tolerated better in dry climates than in humid one. In hot humid regions a higher incidence of nose and throat irritations, shortness of breath and cough is observed among workers chronically exposed to sulphur dioxide. The threshold limit value for industrial environment is set at 5 ppm.

Of the several nitrogen oxides that pollute air, nitrogen dioxide (NO_2) causes the most concern because of its toxicity and concentration in urban smog. On contact with the moist mucosa of the respiratory tract, nitrogen dioxide readily dissolves to form a mixture of nitric and nitrous acids. As with other toxic substances, the reaction to this oxidant gas depends on concentration, duration and pattern of exposure Zye and nose irritation may be caused at 5-1-ppm. A concentration of 10–40 ppm may cause pulmonary fibrosis and emphysema.

Within the rapid pace of industrialization, another dimension has been added, which is the risk of inhalation of many toxic substances which, in the long run, are known to impair the central nervous, respiratory or haemopoietic system. For instance, mercury vapour in the cell house of chloro-alkali plants and carbon disulphide in the viscose rayon units, adversely affect the CNS. Byssinosis resulting from inhalation of cotton dust, silicosis due to inhalation of silica containing dust in many industries like potteries and ceramics, mining, slate pencil manufacture, and asbestosis arising out of inhalation of asbestos fibre, all cause reduction in pulmonary functions. Inhalation of benzene or lead fumes leads to lowering in haemoglobin. It is well established that in such cases, both the work capacity and quality are reduced. It is for the physiologists to make intelligent use of the available physiological techniques to quantify the extent of damage occurring in such adverse environments. When once improvements are brought about through the adoption of preventive control measures, the extent of improvement can also be evaluated using the same physiological techniques in follow up studies. This way, the physiologists, besides restricting themselves only to basic research could also improve the working condition and output of work which will have an immediate impact on society.

It is particularly true in developing countries with enormous human resources which could be effectively harnessed for optimal development, by properly applying the physiological research data in this aspect. It is also true that the large population of the third world countries are subjected more to the extremes of environmental conditions and terrains. Hence, it is desirable to channelise the international efforts and resources for research on the impact of environmental factors on human work performance and health.

REFERENCES

Anderson, K.L., R.E. Elsner, B. Saltin and L. Harmansen. Physical fitness in terms of maximal oxygen intake of nomadic Lapps, Fort Wainwright, Alaska. *USAF Arctic Medical Lab. Tech. Rept.* AAL, TDR-61-53, 1982.

Anderson, K.L. Ethnic group differences in fitness for sustained and strenuous muscular exercise. *Canad. Med. Ass. J.*, 96, 832, 1967.

Balke, B. Work capacity and its limiting factors at high altitude. Ed. W.H. Weihi, *Proc. International Symposium, Intertaken*, Pergamon Press, Oxford, 1964.

Bink, E. The physical working capacity in relation to working time and age. *Ergonomics*, 5, 25, 1962.

Benjer, F.H. Actual energy expenditure in relation to the physical working capacity, *Ergonomics*, 5, 29, 1962.

Benjer, F.H. Relationship between physical working capacity and allowable Calevie expenditure. In *International Colloquim on Muscular Exercise and Training, Darmstadt*, 1968.

Costill, D.L. The relationship between selected physiological variables and distance running performance. *J. Sports Medi. and Fitness*, 7, 61, 1967.

Idem. Physiology of marathon running. *J. Amer. Med. Ass.* 221, 1024, 1972.

Christensen, E.H. and Nielsen, H.E. Die Leistungsfahigkeit der menschlichen Skelettmuskein bei niedrigem sauerstoffdruos. *Skand. Arch. Physiol.* 74, 272, 1936.

Craig, A.B. Limitations of the human organism: Analysis of World records and Olympic Performance. *J. Amer. Med. Ass.* 205, 110, 1968.

Dill, D.B., H.T. Edwards, P.S. Bauuer and F.J. Levenson. Physical performance in relation to external temperature. *Arbeits Physiologic*, 4, 508, 1931.

Dill, D.B., S. Robinson, B. Balke and J.L. Newton. Work tolerance: age and altitude. *J. Appl. Physiol.* 19, 483, 1964.

Dimri, G.P., M.S. Malhotra, J. Sen Gupta, T. Sanpath Kumar and B.S. Arora. Alterations in aerobic-anaerobic proportion of oxygen supply during work in heat. *Europ. J. Appl. Physiol. and Occup. Health* 65, 43, 1980.

Dua, G.L., S.S. Ramaswamy and J. Sen Gupta. Altitude effects on physical work performance. Proc. Int. Symp. on Human Adaptability to Environments and Physical fitness, Ed. M.S. Malhotra, New Delhi, 1966.

Dua, G.L. and J. Sen Gupta. A study of physical work capacity of sea level residents on prolonged stay at high altitude and comparison with altitude native residents. *Ind. J. Physiol. Pharmac.* 24, 15, 1980.

Gagge, A.P., A.C. Burton and H.C. Bazett. A practical system of units for the description of heat exchanges of man with his environment. *Science*, 94, 428, 1980.

Goldman, R.F., E.B. Green and P.F. Iampictro. Tolerance of hot, wet environments by resting men. *J. Appl. Physiol.* 20, 271, 1965.

Hamilton, R.W. Jr. Physiological responses at rest and in exercise during saturation at 20 Atmosphere of He-O_2. Proc. 3rd Symposium on underwater physiology, Ed. C.J.

Lambertson Williams & Wilkins, Baltimove, Maryland, 1967.

Hildes, J.A., O. Schaefer, J.E. Sayed, E.J. Fitzgerald and E.A. Koch. Chronic pulmonary disease and associated cardiovascular disease in Iglooligmints. In: *Circumpolar Health*, Eds. Shepherd, R.J. and Itah, S., Toronto, Ontario, Univ. of Tronto Press, 1976.

Hollman, W. and H. Venrath. Muscular power in high altitude. *Schweiz Wschr, Sport Med.* 14, 27, 1966.

Hurtado, A. Handbook of Physiology Sec. 4 Adaptation to environment pp. 843 American Physiol. Soc. Washington, D.C., 1956.

Karlsson, J. Maximum oxygen uptake in skolt Lapps. *Arctic Anthropol.* 7, 19, 1970.

Lambertson, C.J., S.G. Owen, H. Wendel, M.W. Stroud, A.A. Lurie, W. Lochner and G.F. Clark. Respiratory and cerebral circulatory control during exercise at 21 and 2–0 atmosphere inspired PO_2. *J. Appl. Physiol.* 14, 1966, 1959.

Lanphier, E.H. Interactions of factors limiting performance at high pressures. In: *Proc. 3rd Symp. on Underwater Physiology*. Ed. C.J. Lambertson William & Wilkins, Battmess, Maryland, 1967.

Lind, A.R. A physiological criteria for setting thermal limits for everyday work. *J. Appl. Physiol.* 8, 51, 1963.

Lind, A.R., J.S. Weiner, R.F. Hellon and R.M. Jones. Reactions of mines-rescue personnel to work in hot environment. National Coal Board Medical Research Memorandum No. 1, 1967.

Lloyd, B.B., M.G.M. Jukes and D.J.C. Cunningham. The relation between alveolar oxygen pressure and the respiratory response to carbondioxide in man. *Quart. J. Exptl. Physiol.* 43, 214, 1958.

Majumdar, N.C. Work Capacity, in heat. In: *Med. & Sport*. Vol. 9, Advances in Exercise Physiology. pp. 178. Ed. E. Jokl, S. Karger, Basel, 1976.

Malhotra, M.S., G.L. Dua, S.S. Ramaswamy and J. Sen Gupta. Review of battle physical efficiency tests for altitude 8000–10,000 ft. Min. of Defence, R&D Orgn., DIPAS Report No. 6/66, 1966.

Malhotra, M.S., G.L. Dua, S.S. Ramaswamy and J. Sen Gupta. Variation in physical and mental efficiency of troops at high altitude with age, Min. of Defence, R&D Orgn., DIPAS report No. 2/69, 1969.

Malhotra, M.S. and J. Sen Gupta. Work capacity at altitude. *Med. & Sport*. Vol. 9, Advances in Exercise Physiology. Ed. E. Jokl, S. Karger, Basel, pp. 165, 1976.

Mathew, L. and J. Sen Gupta. Effect of ambient temperature on physical work capacity. *Proc. 8th International Ergonomics Cong.* Tokyo, Japan, 1982.

Michael, E.D., K.E. Hutton and S.M. Horvath. Cardio-respiratory responses during prolonged exercise. *J. Appl. Physiol.* 16, 997, 1961.

Miller, J.N., O.D. Wangensteen and E.H. Lanpehier. Ventilatory limitations on exertion at depth. In: *Proc. 4th Symp. on Under Water Physiology*, Ed. C.J. Lambertson, Academic Press, N.Y., pp. 317, 1971.

Müeller, E.A. Ein leistungs-Puls-Index als Ma der Leistungs fa higkeit Arbeitsphysiologie. 14, 271, 1950.

Idem. Occupational work capacity. *Ergonomics*, 5, 445, 1962.

Nielsen, M. Die Regulation Korpertemperature bei Muskelarbeit. *Skand Arch. Physiol.* 79, 193, 1938.

Pugh, L.G.C.E. Muscular Exercise on Mount Everest. *J. Physiol. Lond.* 141, 233, 1958.

Idem. Cardiac output in muscular exercise at 5800 m (19000 ft). *J. Appl. Physiol.* 19, 441, 1964.

Pugh, L.G.C.E., M.B. Gill, S. Lohiri, J.S. Milledge, M.P. Wood and J.B. West. Muscular Exercise at Great Altitudes. *J. Appl. Physiol.* 19, 431, 1964.

Ramaswamy, S.S., M.S. Malhotra, J. Sen Gupta and G.L. Dua. Comparison of physical work performance between natives and new commerce at high altitude. In: *Proc. Int. Symp. on Human Adaptability to Environments and Physical Fitness*, Ed. M.S. Malhotra, 1966.

Ramaswamy, S.S., D.N. Mathur, N.T. Joseph, B.S. Sarma, T. Sampath Kumar and P.B.S. Pillai. Physical performance and pulmonary functions of athletes at sea level and at moderate altitude. *Min. of Def., R&D Orgn. DIPAS Report No. 2/70*, 1970.

Rennie, D.W., P. Di Prampero, R.W. Fitts and L. Sinclair. Physical fitness and respiratory function of Eskimos of Wainwright, Alaska, *Arctic Anthropol.* 7, 73, 1970.

Robinson, S. The temperature regulation in exercise. *Paediatrics*. 32, 691, 1963.

Rode, A. and R.J. Shepherd. Cardio-respiratory fitness of an arctic community. *J. Appl. Physiol.* 31, 519, 1971.

Rowell, L.B., K.K. Kranning, J.W. Kennedy, and T.C. Evans. Central circulatory responses to work in dry heat before and after acclimatisation. *J. Appl. Physiol.* 22, 509, 1967.

Salzano, J.V., W.H. Bell, W.B. Weglicki and H.A. Saltzman. Metabolic Respiratory and Haemodynamic Responses of Exercise at Increased Oxygin Pressure. In: *Proc. 3rd Symp. on Underwater Physiology*. Ed. C.J. Lambertson, Williams & Wilkins, Baltimore, 1967.

Salzano, J., E.M. Overfield, D.C. Rausch, H.A. Saltzman, J.A. Kylstra, J.S. Kelley and J.K. Summit. Arterial blood gases, Heart rate and Gas exchange during rest and exercise in men saturated at a simulated sea water depth of 1000 ft. In: *Proc. 4th Symp. on Underwater Physiology*. Ed. C.J. Lambertson. Academic Press, N.Y., pp. 347, 1971.

Sen Gupta, J., M.S. Malhotra and S.S. Ramaswamy. Exercise dyspnea and work performance at sea level and at high altitude. *Indian J. Physiol. Pharmac.* 16, 47, 1972.

Sen Gupta, J., S.S. Verma, N.T. Joseph and N.C. Mazumdar. A new approach for the assessment of endurance work. *Europ. J. Appl. Physiol.* 33, 83, 1974.

Sen Gupta, J., G.P. Dimri and M.S. Malhotra. Metabolic responses of Indians during sub-maximal and maximal work in dry and hot humid heat. *Ergonomics*, 29, 33, 1977.

Sen Gupta, J., Y. Venkataswamy and G.P. Dimri. Capacity for continuous and intermittent prolonged work under heat stress. *Min. of Def R & D Orgn. DIPAS Report No. 7/77*, 1979.

Sen Gupta, J., S.S. Verma and N.C. Mazumdar. Endurance capacity for continuous effort in terms of aerobic-anaerobic fraction of oxygen supply. *Ind. J. Physiol. Pharmac.* 23, 169, 1979.

Sen Gupta, J. and M.S. Malhotra. Why are we so week in sports? A physiological appraisal. *Med. J. Armed Forces of India*, XXXIV, 324, 1979.

Sen Gupta, J., Y.V. Swamy, G.P. Dimri and G. Pichan. Physiological responses during work in hot humid environments. *Int. J. Physiol Pharmac.* 25, 339, 1981.

Sen Gupta, J., Y.V. Swamy, G.P. Dimri and G. Pichan. Physiological responses during continuous work in hot dry and humid environment. *Ind. Jour. Biomet*, 26, 129, 1984.

Shepherd, R.J. Work physiology and activity patterns. In: *IBP Synthesis Volume: Circumpolar Peoples*. Ed. Milan, F., Cambridge Univ. Press. U.K., 1975.

Sime, F., D. Penaloza, L. Raiz, N. Gonzales, E. Covarrubras and R. Postigo. Hypoxaemia. Pulmonary hypertension and low Cardiac output in new comers at low altitude. *J. Appl. Physiol.* 36, 561, 1974.

Swamy, Y.V., G. Pichan, S.S. Verma and J. Sen Gupta. Evaluation of different heat stress indices on the basis of physiological responses. Ind. II *Proc. XV Commonwealth Defence Conference*, Ghana, 1978.

Taylor, H.L., A.E. Henschel and A. Keys. Cardiovascular adjustments of man in rest and work during exposure to dry heat. *Amer. J. Physiol.* 139, 583, 1943.

Ward, M. A clinical study of cold and high altitude. Mountain Medicine, Crosby Lockwood Staples, London, 1975.

West, J.B. Climbing Mt. Everest without oxygen: An analysis of maximal exercise during extreme hypoxia. *Resp. Physiol.* 52, 265, 1983.

Wholen, R.E., H.A. Saltzman, D.H. Holloway, H.D. Melntosh, H.O. Sieker and I.W. Brown Jr. Ventilatory and cardiac dynamics under hypperbaric states. *Amer. J. Cariol,* 15, 638, 1965.

Williams, C.G., G.A.G. Bredel, C.H. Wyndham, N.B. Strydom, J.E. Marrison, J. Peter, P.W. Flaming and J.S. Word. Circulatory and metabolic reaction to work in heat. 17, 625, 1962.

Wyndham, C.H., W. Benwer, M. Vander, M.F. Paterson and M.G. Devine. Practical aspects of recent physiological studies in Witweters-rand gold mines. *J. Chem. Mining Soc. S. Afr.* 53, 207, 1953.

20

Psychological Dimensions of Environmental Management

Uma Shanker

This topic has been chosen for a variety of reasons. Firstly, management of the environment is essential for improvement in both the quality of the environment and the quality of human life. This emphasizes the importance of taking environmental factors into account in the developmental activities of our country. Second, responding to the call given by our Prime Minister to prepare our country for the 21st century, we psychologists have an important role in building modern India by providing psychological perspectives and suggesting paradigms that would help solve the diverse problems of our contemporary complex society. Third, we recognize the fact that as psychologists we are concerned with the understanding and prediction of human behaviour which is essentially a function of two major factors: (1) man himself, and (2) the environment that surrounds him.

Concept of Environment

Before we consider management of the environment from a psychological point of view, it would be necessary to indicate the sense in which the term 'environment' is used. Literally it means surroundings. Hence, it is generally used in a narrow sense by different groups of people working in different areas while referring to a particular kind of surrounding. When physical scientists talk about environment, they generally refer to the physical environment which comprises the three interlocking systems—the atmosphere, the hydrosphere and the lithosphere. Biologists often refer to the biological environment consisting of all living organisms of the biosphere. Similarly, social scientists refer to the social environment, cultural environment, economi environment, industrial environment and organisational environment, meaning thereby a particular kind of setting.

Gestalt psychology has conceptualized environment "...as a complex stimulus field whose properties emerge from and are determined by the organization and inter-relationships of its component parts. The person does not respond to an object in isolation from its environmental field, but to the field—like properties of that object created by the environmental context of which it is a part" (Ittelson et al., 1974). In fact, the behaviour and experience of an individual in response to his environment can be understood only in this manner.

Koffka (1935) distinguished the 'geographical' environment from the 'behavioural' environment. He described 'geographical' environment as the external setting existing apart from the individual who perceives it, and the 'behavioural' environment as the setting recreated by the interpretations and meaning given to it by the particular person observing it. The person is himself a part of both environments. His behaviour and experience reflect the balance of influences resulting from the interaction of the two worlds, that is the world as is and the world as perceived by the person. The same physical environment may be perceived by different individuals in different ways depending upon their own individual experiences, needs and motivations. In other words, the internal environment or the psychological environment of an individual influences his perception of the physical environment and also his attitude and behaviour towards it. Thus it may be distinguished from the social environment "... which consists of other people and the things associated with them" (Kelvin, 1970).

Thus, it can be easily seen that environment is more than just physical surroundings. It also includes, the social environment and the psychological environment. It may, therefore, be viewed in its totality comprising the whole set of natural or biophysical and man-made or socio-cultural systems in which man and other organisms live and interact. Whereas the biophysical aspects of the environment affect the growth and development of an individual or a community, the socio-cultural aspects influence the attitude and behaviour of an individual or a community, which itself has developed as a result of human interaction with one another as well as with the natural environment.

Ever since man appeared on the earth, he has been an integral part of the environment, which is itself an outcome of the environmental processes. However, his attitude towards the environment has changed continuously throughout history. Early man found himself helpless before nature. He therefore, held that natural objects were animated by gods and hence the natural phenomena were the creations of gods. He consequently worshipped nature, the gods of rivers, seas, mountains and trees were placated through ceremony and sacrifices. Since primitive man had limited needs, the extent and quality of damage to the environment were also insignificant and the harmony of nature was not disturbed. Gradually man learnt to conquer some of the vicissitudes of nature. He could now use nature to his own advantage and thus started interfering with the environment. With scientific and technological advancements, modern man's views also changed. Modern scientific explanations allow no room for natural spirits with the lawful universe being measured and understood without recourse to magic or religion. Man, therefore, considered himself to be more powerful than nature. He started perceiving environment as a resource to be exploited rather than a system to be maintained. The extent of human intervention has grown to a point where it has produced vast and disruptive changes in the environment. Deforestation, soil erosion, salinization of soil, industrialization, urbanization, depletion of natural resources like, minerals and energy resources, extinction of several living species and growing pollution are some of the examples of environmental degradation leading to the present day environmental crises. These ecological problems include diverse aspects ranging from the economic, social, psychological problems of human settlements to the management and use of natural resources and the conservation of natural habitat.

Environmental Problems

Obviously, maintaining and improvising the quality of the environment, which also includes quality of life, has become established as one of the major aims of public policy at national and international levels. Despite the energy crisis, high inflation economic recession and increased levels of unemployment, there is growing public concern about conservation of natural resources and the protection of the environment. The environmental hazards of industrial activities such as the Bhopal gas tragedy are matters of utmost public concern and require strict implementation of environmental legislations. In developed countries like the U.S.A. environmental legislations are at a high cost to industries. The United States Commerce Department calculated that in 1975, capital expenditures for air and water pollution control amounted to $ 7.7 billion, and the Council on Environmental Quality had predicted that industry would spend approximately $ 258 billion just to meet the provisions of existing legislation during 1975–1984. In Italy a recent disaster in a chemical plant is causing continuing anxiety. In Holland, Hogovens were prevented from building a steel plant because of worries about the pollution of the Rhine. In Britain and Norway there are recurrent worries about oil slicks from tankers and oil rigs. In virtually every European country the public outcry against the dangers of building and operating nuclear power plant has been sufficient to hold back nuclear energy programmes.

Human activities have affected environment in various ways. The exploitation of environment has resulted in changes in eco-systems in many parts of the universe. And, therefore, the nature of environmental problems are different in various parts of the world. Environmental crisis may be viewed as a situation demanding immediate corrective measure, if possible, to avert deterioration, damage and destruction of the affected system (Strahler and Strahler, 1977). Most of these problems faced today by human beings are to a large extent due to their own negligence. If people had thought of applying the principles of science and technology and using psychological techniques in an appropriate manner, we might have avoided most of these problems.

These environmental problems may be divided into three categories depending upon their magnitude: global, regional and local.

Global problems pertain to the biosphere, affecting nearly all countries. Into this category fall the most widely discussed and threatening problems, including, for example, those caused by persistent pesticide residues which through the actions of wind, water and living carriers find their way into the biosphere beyond the country in which the chemicals were applied. Other examples of global problems are the burning of fossil fuels, affecting the carbondioxide balance and the sulphurdioxide loading of the atmosphere, and the levels of the constituent elements of the stratosphere; the pollution of the oceans from land sources, oil spillage, or ship dumping on the high seas; and man-influenced changes in global climatic patterns.

Environmental problems which are not restricted to the boundary of a country but encompass a wider area covering more than one country, fall under the category of regional problems. A typical example is the effect of river basin development on riparian countries, upstream or downstream.

Local problems are confined to the boundaries of a particular country; for example, the extirpation of a wildlife resource, the creation of an aesthetic blight, or the eutrophication of a lake from fertilizer run off or discharge of domestic sewage.

Thus, environmental problems differ in their dimensions. They may also differ in the amount of time they take to become visible. For example, while a global problem may eventually result from the gradual build up of carbon dioxide in the atmosphere over a long period, the effects of persistent pesticides, can be seen more immediately. Another variant related to timing is the degree of certainty. The greater the time-span for the cause-effect relationship to be observed and understood, the greater the uncertainty as to its manifestation, but the continuation of presently observable consequences is far more certain to be perceived.

Two other variables may be noted: magnitude and reversibility. Magnitude cannot easily be compared, because effects are of different types, occur in different places, and affect different aspects of life systems. Reversibility concerns the possibility of returning an ecological systems to its former state. For example, a lake in an advanced state of eutrophication is virtually irreversible, the extinction of a species is absolutely so. On the other hand, it is possible to end pollution from particulate matter in the smoke of an industrial plant and to restore the ambient air quality. The dimensions of time, certainty, magnitude, and reversibility combine to produce the dimension of urgency.

The environmental problems of developing countries can be broadly divided into two more categories: effects of poverty, and effects of economic development.

Under conditions of poverty the biophysical environment often exhibits the ravages of long years of mismanagement (overgrazing, erosion, denuded forests, surface water pollution etc.). Not merely the "quality" of life but life itself is endangered for it is often very difficult and sometimes impossible for the environment to renew its life supporting capabilities. Developing countries assign the highest priority to finding solutions to problems of this nature. Here the principal concern is to rehabilitate the environment that has gone through a long period of deterioration.

The other set of problems accompanies the process of development itself. Agricultural growth, for example, calls for construction of irrigation and drainage systems, clearing of forests, use of fertilizers and pesticides—all of which have environmental and health implications. Similarly, the process of industrialization could well result in the release of pollutants and in other environmental problems related to the extraction and processing of raw materials. It, however, does not mean that development, causes destruction of the environment. The developing countries cannot but look up planned development as an instrument to improve the quality of life, but we should move away from the single dimension model equating the growth of Gross National Product with development. We need to put emphasis on the qualitative improvement of life as a whole rather than the quantitative growth of various sections of economy. (Gandhi, India, Inaugural function of the National Committee on Environmental Planning and Coordination at New Delhi, 12 April, 1972, In "Indira Gandhi on Environment" Department of Environment, New Delhi, 1984).

As I have already mentioned, these problems have been caused by the human interventions in the process of using the environment for various needs. The use of environment for mankind is an acceptable truth. The difference exists in the way it is used. The old concept of using the environment and discarding will have to give way to the recycle context of perpetual renewal and re-use.

Psychological Dimensions

Psychologists' interest in the environment is manifold. Our first concern is regarding the psychological problems as creation of the built environment. For example, population density, intercity decay, and pollution create environmental stress for urban man. We need to have a more empirical analysis of the relationship between the behaviour of man and his urban environment, which would help in urban planning and developing new towns. Our second concern is the natural environment. If man has to live in harmony with nature, a better balance should be found between the natural environment and the human activity. It is, therefore, necessary that man recognises that he can no longer exploit the earth's resources freely forever. In other words, it would mean a deliberate attempt to change the man's attitude and behaviour towards the environment. Thus on a more theoretical level, some basic psychological processes are involved. These would include the role of perception and cognition in the man/environment inter-relationship and man's behaviour. In this connection, the stimuli affecting perception, the spatial properties of the environment influencing patterns of behaviour and the environment as a factor in growth and development and its role in learning are worth considering. For understanding these processes, a knowledge of the values, attitudes and the social and cultural norms brought to the environment by people living there is very crucial.

It is obvious that the environmental degradation is a matter of great concern the world over and the psychologists have a dominant role to play in improving the world environment. As a scientific community our recommendation can be twofold: (i) preventive, and (ii) curative measures.

Psychologists can, based on the scientific study of the man and environment inter-relationship, recommend parameters for taking steps by the people at large to refrain from indulging into activities which cause environmental degradation. To take it a little further, psychologists can study the physical and the social environment and the focus of attention will be on the individual and group behaviour. Because "the behaviour of the individual is a function of the order which he perceives in his environment, in the physical environment this order is mainly determined by the physical properties of objects but in social environment it is created and maintained by man himself; and the order which he creates is predominantly based on his system of values" (Kelvin, 1970).

This approach should help in understanding the value system and the specific group behaviour in their environment. Let us now consider some of the situations. The tribal groups in Bihar started their "tree war" in 1977 on forest-related issues against the state administration. The native sal trees of the area were being replaced by teak, which is purely commercial timber and is of no value to the tribals or their cattle. Since mid-1980, the tribal opposition took the form of the Jungle Kato Movement. As a result, hundreds of trees are being felled indiscriminately by the tribals. This particular behaviour, which is detrimental to the state of environment in the region, must be understood in its proper perspective i.e. in terms of the psycho-social, cultural and economic needs of that particular society. For long time, the forest has been the natural abode of the tribal population in the area and it is also the main source of their livelihood. Due to rapid industrialization and urbanization, the natural vegetation cover got reduced. To cover the loss, the government classified forests of the region as reserved and protected. As such, the tribals have been evicted from the forest areas and they have not been provided with alternative sources of food, fodder and fuel. Even basic amenities like water is becoming difficult for them because of the pollution of streams by various kinds of industrial activities (Agarwal et al., 1982). It is thus an irony that the tribals who depended on the forest and loved trees are having conflict with it. In such a situation, psychologists, sociologists and other social scientists together with the environmentalists, can work to find amicable solution to the problem of environmental degradation and help resolve the conflict.

It is quite obvious from the above that any such programme to improve the quality of the environment cannot be successful until local community is convinced about its advantages and is benefited by it. In fact, the community participation is a must for the success of these programmes. This can be sought in two ways by educating and motivating the local people to get involved or by offering them material incentives. Voluntary agencies usually opt for the former and the government agencies for the latter (Agarwal et al., 1982).

However I feel that the material incentive alone may not sustain for long. The local community must be educated to develop environmental awareness and proper attitudes towards the environment and an urge to participate in its protection and improvement. In fact, participation enhances learning, whether it is in the field work or in other efforts for environmental change.

During the past decade, there has been increasing debate over what really constitutes effective and appropriate means of community participation. An instructive example of participation in environmental management came from Colombia which provided a comprehensive programme with highly developed features devoted to environmental education and management (Santander, 1975). This was aimed at farmers, fishermen, forest workers and other rural groups for the purposes of introducing conservation of natural resources and to check soil erosion, over-fishing and over-exploitation of forests. It directly involved the people concerned. Similar to this, consumer education could be another area which may involve the people directly for the betterment of the environment.

From what has been stated so far, it is clear that for the proper development and progress of a country, management of environment is highly essential. But in order to be able to manage environmental, education of the masses about the environmental resources and their proper utilization with the assistance of tested psychological materials and techniques would be equally essential and fruitful. In terms of these considerations I could now deal with the following:

1) Environmental Management.
2) Environmental Education.
3) Environmental Psychology.

Environmental Management

The environment consists of many interacting components. The management of the environment depends upon an understanding of its components and it helps avoid unhealthy influences/activities like pollution, erosion and the wastage of resources by irreversible damages. To prevent such types of environmental degradation is even more challenging than to merely redress them after they have occurred.

Environmental management as a discipline by itself is growing rapidly. In no way it proposes to halt economic growth and to stop technical development rather it aims at achieving that sustainable rate of economic growth which is necessary to meet man's material needs whilst conserving scarce natural resources and protecting both the external environment and the internal environment.

The government officials have to manage the process of environmental protection on a regional, national or international level enabling citizens to take the advantages of modern science and technology and enjoy the benefits of the natural resources available whilst minimising the social costs which are likely to occur through shortages, pollution and social conflict. To the industrialist on the other hand, environmental management means ensuring that critical decisions are taken with the environmental problem in mind. This means that he takes his decisions consciously knowing what their impact is likely to be on the environment and is ready to defend himself or his organization against any attacks that might be forthcoming in relation to the overall benefit he is seeking to achieve. Both the government official and the industrialist are concerned to 'manage' from different points of view the process by which a balance is struck between technological and economic progress on the one hand and the conservation or the improvement of the natural and man-made environment on the other.

Environment management, therefore, is a challenging task and involves developing innovative approaches such as:

1) to assess the impact of technology on the environment;

2) to estimate the economic cost of meeting environmental standards;

3) to predict future trends in environmental management;

4) to promote case studies with regard to environmental problems arising from different kinds of industries;

5) to encourage and organise public participation in planning new projects;

6) to formulate strategies and plans for achieving social and political support for economically and technically viable projects;

7) to design organisation structures and management systems, which will encourage managers at different levels to take environmental factors into consideration while taking decisions; and

8) to analyse and resolve conflicts arising among various interest groups.

Keeping in view the above mentioned approaches, I may mention that those who have interest in environmental management may like to investigate topics such as:

1) environmental issues and problems such as ecology, natural resources and pollution;

2) natural resources and the environment-depletion of resources, quality of environment and conservation;

3) energy and the environment-non-conventional energy sources;

4) environmental regulations and legislations;

5) governmental and voluntary agencies and interest groups—their roles in environmental management;

6) public attitude and environmental management; and

7) environmental conflicts—causes and remedies.

Environmental Education

Although environmental education may be defined in a number of ways, they tend to emphasize similar points.

In the Nevada conference of the International Union for the conservation of Nature and National Resources in 1970, Environmental Education has been defined as "... the process of recognising values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the interrelatedness among man, his culture and his biophysical surroundings. Environmental education also entails practice in decision-making and self-formulating a code of behaviour about issues concerning environmental quality". According to Wheeler (1975) "Environmental education and the exercise of citizenship go hand in hand, the opening up of opportunities for public participation in decision-making is the most important of all means to environmental education, which should aim at developing a critical, moral and aesthetic awareness of our surroundings".

In short, environmental education may be considered as an action process, which aims at providing an environmentally oriented education system. It is assumed that this would help resolve the environmental crisis by preparing environmentally conscious citizens. Thus, it is not a new discipline but a new dimension, which emerged in the existing form in the 1970's.

Environmental degradation in terms of undesirable impacts of technology and economic activity became a matter of international concern by the end of the 1960s. This ultimately prompted United Nations to convene a conference on human environment in Stockholm in 1972. The August body of international experts and government representatives of different countries stressed the role and need of environmental education—of both the public and the specialists in the solution prevention and anticipation of these pressing problems. In response to the Stockholm Recommendations, UNESCO and UNEP set up an International Environmental Education

Programme with a view to promoting exchange of information and experiences in the field of environmental education. Besides the formal and non-formal education, mass media can also perform an effective educational function. It is particularly more important in creating an awareness and motivating people for participating in the task of environmental management surveys of attitudes towards pollution control and specific environmental problems showed a reasonable correlation between general awareness of a given problem and the news coverage given to that problem. But these have limited roles. When surveys were followed by testing of factual knowledge about a particular problem, the sharp limits of the educational role of the media were clear (Emmelin, 1977). Deep-rooted thinking on manenvironment interrelationships, concern about conservation of resources and ecological balance, and skills required to participate effectively in the solution of environmental problems, can be developed only by providing proper environmental education.

On the basis of the recommendations of the Stockholm Conference, five broad areas have been identified for furthering the task of environmental education. These are:

1) environmental aspects of the management of natural resources;

2) planning and management of human settlements;

3) identification of major pollutants and their control;

4) educational, socio-cultural and informational aspects of environmental issues; and

5) environment and development.

While formulating the action plan, these were categorized under three sections—environmental assessment, environmental management and other supporting measures in the form of education and training programme, financial and technical assistance.

A number of conferences and workshops have followed the Stockholm Conference of crystallize the environmental education concepts and to discuss and recommend appropriate measures to promote environmental education as established by the Tbilisi Conference (UNESCO 1977), are to develop the following qualities in individuals and social groups:

1) an awareness of, and sensitivity to, the environment and its associated problems;

2) basic knowledge and understanding of the environment and its problems;

3) attitudes and social values, which are in harmony with the environmental quality;

4) skills to solve environmental problems;

5) ability to evaluate environmental measures and education programmes in terms of ecological, social, political, economic and other factors; and

6) a sense of responsibility and urgency regarding environmental problems so as to ensure appropriate action to solve them.

It, thus, requires a comprehensive view about the environment which needs to be reflected in the design and structure of educational content, educational strategies and methods of learning. There is need to provide environmental dimension in the existing curricula cutting across different disciplines in the formal education system. Besides, various professional and scientific groups and the public require the essential knowledge about the environment in different ways because of their varying needs.

During the decade, several efforts have been made in different parts of the world to develop environmental education curricula for schools. Collins (1977), Reid and Shaw (1975), Lines and Bolwell (1978), Madders (1975), and Kominski (1975) dealt with various aspects of environmental education for the primary and secondary schools. The problem of developing teacher's sensitivity to the environment existed in all continents but has been more acute in developing countries. While some progress has been made by introducing flexibility into curricula and by short duration in-service teacher-training programmes much has yet to be done to achieve an integrated environmental approach. Several modules have been developed by UNESCO for providing Environmental Education for pre-service teacher training programmes (e.g. Cortes et al., 1983; Sinha et al., 1985). But, the diversity of the environment, particularly of large countries, requires each teacher to frame his teaching to suit local conditions. In the absence of sufficient teaching materials, it is an arduous task. There is a great need to produce more effective indigeneous teaching materials. Psychological researches may help in identifying the needs of the different groups and developing suitable materials for effective teaching learning process.

At the tertiary level, postgraduate education in environment in several universities offers different kinds of programmes such as environmental planning, and resource development and training in research and investigation methodologies applicable to environmental system.

During the past decade, the development of environmental education on the previously mentioned lines proceeded in many countries and public awareness was enhanced by it. Many environmental groups have been successful in highlighting environmental issues and affecting the policy-making process. For example, Sweden's Parliament approved cessation on chemical spraying of forests for a period of at least one year of pressure from environmental groups (WER, 1980). In India, due to the protest from the citizen groups and environmentalists the proposal for siting of the Thal—Vaishet Fertilizer Project near Bombay and dams at Silent—Valley and Tehri have been shelved and a committee has been set up to study the impact of these projects on the environment (Agarwal et al., 1982).

Environmental Psychology

According to Ittleson et al. (1974) "Environmental Psychology . . . sees man not as a passive product of the environment, but as a goal directed being who acts upon his environment and who in turn is influenced by it" (p. 5). Thus, in discussing or evaluating Environmental Psychology a fundamental distinction may be drawn between pure Psychology and Environmental Psychology. Psychologists study man by taking him away from his everyday millieu in experimental and controlled settings for establishing discrete and quantifiable sub-behaviour. For example an experimenter may spend a good deal of time and money exploring the effects of a variable in isolation, which may hardly operate in isolation in natural setting. Yet by studying this variable in this fashion, the experimenter may manipulate situation according to his needs which enables him to deduce propositions that could not be arrived at under uncontrolled condition i.e. natural setting. On the other hand, Environmental Psychologists would prefer to study man in his millieu. The major concern, therefore, is to study the man environment interrelationship, which is ever changing and complex. In this attempt it brings together relevant ideas drawn from different disciplines such as sociology, social anthropology, geography and economics. In fact, by pooling resources, within disciplines as well as across disciplines, the chances of discovering better answers and strategies are maximized. George Miller in his 1968 presidential address to American Psychological Association, stressed the need for "giving away" psychology to the people because there can never be enough psychologists to help solve the problems confronting people. The same point holds true in scientific research as well. Besides encouraging people working in different disciplines to have psychological perspective in viewing problems, psychologists can also benefit from their viewpoints. Environmental problem is one of the examples of the value of shared perspectives. As mentioned earlier, environmental problems can be solved following an interdisciplinary approach. But there are very few examples of interdisciplinary research, although one can find a number of research work being carried out in various disciplines on similar problems.

Environmental psychology is comparatively a new field of research. It, therefore, has many uninvestigated and unsolved problems. Since it follows an interdisciplinary approach. It's research material is widely dispersed. In fact, being a developing field of inquiry, it seeks to formulate theories to back up its empirical observations. However, there are few noted works to lead the way. Hebb's (1949) research on early environmental simulation and on sensory deprivation was one of the first attempts in psychology to focus on the importance of the physical environment. Barker and Wright (1949), Barker (1955, 1968) worked on ecological psychology predating the current enthusiasm for environmental studies. Barker (1968) advanced the hypothesis that behaviour is best studied in its natural environment. Most of our activities take place in well defined physical settings. Each of these settings or environments imposes a specific type of behaviour on those who enter it. These studies are important as they may help in answering question like how do environments select and shape the people who inhabit them? What are the structural and dynamic properties of the environments to which people must adapt? Craik (1966, 1968), Wohlwill (1966, 1970) and Kates and Wholwill (1966) have identified relevant work and articulated directions and potentials in this promising field. Wohlwill (1970) points out three forms of relationship between behaviour and the physical environment. Firstly, behaviour occurs in an environmental context that limits and shapes options and repertoire. Secondly environmental dimensions and qualities influence behaviour and personality of the individual in a variety of ways. Most of these variables such as noise, crowding and heat may be called environmentally produced stress variables. And lastly, some behaviour may be considered as direct response to environmental settings, some may be sought, and others may be avoided.

In this kind of relationship environment serves as a motivating force and has three facts: (i) affective and attitudinal responses to environmental features; (ii) approach and avoidance behaviour to different attributes of the environment; and (iii) adaptation to environmental condition (Heimstra and McFarling, 1979).

The influence of a variety of environmental characteristics on a wide range of dependant variables has produced the most substantial research. Krech et al. (1960, 1962) have used interdisciplinary approaches, Scrimshaw (1967), Ricciuti (1968), Brockman and Ricciuti (1971), Pollitt and Ricciuti (1969) and Canosa (1968) on malnutrition and Dennis and Najarian (1957) on environmental deprivation follow the same conceptual approach Sommer (1966, 1969) and Hall (1966) worked on "proxemics", the field of spatial behaviour, "Territoriality" has been much in vogue and several studies have explored human territoriality (Patterson, 1968; Roos, 1968; Sommer and Becker, 1969; Hundert and Greenfield, 1969). As with territoriality, crowding has also been studied extensively in animals. Baxter and Deanovich (1970) studied the anxiety-arousing properties of inappropriate crowding Griffith and Veitch (1971) investigated the effects of hot and crowded condition on human behaviour "Cognitive map" on the image of the city' (Lynch, 1960) results from both the personal characteristics of an individual and the personal characteristics of the city. The 'cognitive map' of a particular city held by its citizens can be useful in providing information about the impact of the city and ways residents relate to it Milgram (1970) includes these maps as one of many approaches to study the adaptation behaviour of people to urban situation and complex environmental conditions.

In spite of the fact that Environmental Psychology emerged as a distinct field in early 60s, not much work has been done. It is mainly because of the problem in selecting suitable strategy for studying human behaviour in diverse natural settings. It is immaterial which techniques are used to study the specific behaviour as long as the appropriate data is forthcoming to suit the purpose of the study. It may, however, be mentioned that a good research design should be able to identify the nature of variables most relevant to behaviour under investigation; to utilize the most suitable methods for studying this behaviour; and to produce key information about the behaviour. Some of the research techniques, which may be useful in conducting investigations in this field of Psychology are—Experimental method, naturalistic observation/Holistic methods, survey method, field study, exploratory method and the case study.

From the preceding discussions, one can easily discern the importance of environmental management through environmental education and environmental psychology. Environmental education uses the psychological principles and methods in disseminating the knowledge derived from the findings of various disciplines for creating an awareness and a better understanding of environmental problems. It should be aimed at all levels in both formal and non-formal education for every individual irrespective of his age. The process of environmental education depends heavily on the findings of psychological researches with reference to cognition, perception, attitudes, behaviour, motivation, emotion and other individual and social dimensions because the ultimate purpose of the environmental education programme is to charge attitude and behaviour of man towards environment from one, where man has only privileges and no obligations to the one where man has privileges but also obligations to ensure a high quality living environment. It must look outward to the community involving the individual in an active problem-solving process within the given framework of the community. It also aims at motivating and creating a sense of responsibility and commitment to create a better environment. The challenge of environmental education, however, lies in its implementation. There are a number of constraints in implementation and its success will depend on strong continued support from policy makers, administrators, educational planners and the formal and non-formal educational authorities and others who are responsible for bringing about change in the educational system and the community.

While environmental education is a way of implementing the goal of environmental protection, environmental psychology is a scientific study of the dynamic interchange between man and his environment. Since Environmental Psychology is concerned with the study of man's behaviour in his natural environment, it creates natural problems for researches to control or manipulate the different variables which may be influencing the man's behaviour. Therefore, the key issue is that of selecting a suitable strategy for studying human behaviour in various natural settings. Because of the complex nature of physical settings within which human activity occurs, our task is the development of research techniques which are sensitive to this complexity. As we know that it would not be advisable to change the physical environment nor we would like to restrict the human behaviour in his natural environment alone, it poses a serious challenge for the environmental psychologists. No single strategy can give the desired results. So it would be essential on the part of the researcher to understand not only the complexity of the environment in which the human behaviour occurs but also the implications of the predictions made for the future behaviour under the similar environmental conditions. I may, therefore, suggest that the various techniques such as survey research, holistic research the field study, exploratory research and case study method may be employed for determining the human behaviour of various groups and societies in different parts of our country having diverse environmental conditions. The results of such studies, I feel confident, would help to a great extent the planners, administrators and decision-makers in introducing suitable measures for not only making environmental education programmes effective but also using them for planning and implementation of various environmental management programmes. Some two decades after the emergence of environmental psychology as a discipline, the research results are beginning to be applied to various environmental projects. Harold Proshansky cautions, however, that " . . . the integration of psychological findings and planning will be a slow process" (Levine, 1984).

In order to be able to achieve the goals of self-sufficiency and all round development of the country I feel that there is a great need for conducting psychological investigation on a variety of problems, some of which have been pointed out in course of my talk so far. Other problems could also be formulated for research work in this relatively unexplored field of environmental management. Viewed in this light, the various departments of psychology and management education could profitably incorporate environmental psychology and environmental education in their respective courses and research endeavours.

To conclude, I would make a fervent appeal to the psychologists, sociologists, geographers, architects, educationists and other academicians working in institutions, research organizations and universities to view the topic of environmental management from a wider perspective and to conduct meaningful studies with a view to arriving at workable remedial measures for the outlined problems that confront man in this everchanging and dynamic universe.

REFERENCES

Agarwal, A., R. Chopra and K. Sharma, (eds.) *The State of India's Environment 1982: A Citizen's Report*. New Delhi Centre of Science and Environment, 1982.

Barker, R.G. and H.F. Wright. Psychological Ecology and the Problem of Psychosocial Development. *Child Development*, 20, 131–143, 1949.

Barker, R.G., *Mid-west and Its Children*. Harper and Row, New York, 1955.

Barker, R.G., Ecological Psychology. *Concepts and Methods of Studying the Human Behaviour*. Stanford University Press, Palo Alto, California, 1968.

Baxter, J.C. and B.S. Deanovich. Anxiety Arousing Effects of Inappropriate Crowding. *Journal of Consulting and Clinical Psychology*, 35, 174–178, 1970.

Brockman, L.M. and H.N. Ricciuti. Severe Protein—Calorie Malnutrition and Cognitive Development in Infancy and Early Childhood. *Developmental Psychology*, 4, 312–319, 1971.

Business Week, April 4, 72–73, 1977.

Canosa, C.A. Ecological Approach to the Problems of Malnutrition Learning and Behaviour. In N.S. Scrimshaw and J.E. Gordon (eds.), *Malnutrition, Learning and Behaviour*, MIT Press, Cambridge, Mass, 389–396, 1968.

Collins, M.A.J. How to Develop and Test Your Own Curriculum. *Science and Children*, National Science Teachers Association, Washington D.C. 14, 6, 11, 1977.

Cortes, L.P., W.P. Galvante, V.L. Rodriguez and E.Y. Basa. *Environmental Education: Module for In-service Training of Science Teachers and Supervisors for Secondary Schools*, UNESCO, Paris, 1983.

Craik, K.H. The Prospects of Environmental Psychology. *IPAR Research Bulletin*. Institute of Personality Assessment and Research, University of California, Berkeley, California, 1966.

Craik, K.H. The Comprehension of the Everyday Physical Environment. *Journal of the American Institute of Planners*, 34, 29–37, 1968.

Dennis, W. and P. Najarian. Infant Development Under Environmental Handicap. *Psychological Manographs*, 71, Whole No. 436, 1957.

Department of Environment. *Indira Gandhi on Environment*, Department of Environment, Government of India, New Delhi, 1984.

Emmelin, L. Environmental Education Programmes for Adults. In *Trends in Environmental Education*. UNESCO, Paris, 1977.

Griffith, W. and R. Veitch. Hot and Crowded: Influences of Population Density and Temperature on Interpersonal Affective Behaviour. *Journal of Personality and Social Psychology*, 17, 92-99, 1971.

Hall, E.T. *The Hidden Dimension*, Doubleday, Garden City, New York, 1966.

Hebb, D.O. *Organization of Behaviour*. Wiley, New York, 1949.

Heimstra, N.W. and L.H. McFarling. *Environmental Psychology*, Brooks/Cole Publishing Company, California, 1974.

Hundert, A.T. and N. Greenfield. *Physical Space and Organisational Behaviour: A Study of an Office Landscape*. 77th Annual Convention, APA, 601–602, 1969.

Ittelson, W.H., H.M. Proshansky, L.G. Rivlin and G.H. Winkel. *An Introduction to Environmental Psychology*. Holt, Rinehart and Winston, New York, 1974.

Kates, R.W. and J.F. Wohlwill. (eds.) Man's Response to the Physical Environment. *Journal of Social Issues*, 22, 1–140, 1966.

Kelvin, P. *The Bases of Social Behaviour*. Holt, Rinehart and Winston, London, 1970.

Koffka, K. *Principles of Gestalt Psychology*. Harcourt Brace Jovanovich, New York, 1935.

Kominski, J.W. Forming an Ecology. *Club New Era*, Cambridge, U.K. 56, 16, 1975.

Krech, D., M.R. Rosenzweig and E.L. Bennett. Effects of Environmental Complexity and Training on Brain Chemistry. *Journal of Comparative and Physiological Psychology*, 53, 509–519, 1960.

Krech, D. Relation between Brain Chemistry and Problem—Solving Among Rats Raised in Enriched and Impoverished Environments. *Journal of Comparative and Physiological Psychology*, 55, 801–807, 1962.

Levine, C. Making City Spaces Lovable Places. *Psychology Today*, 18, 6, 1984.

Lines, C.J. and L.H. Bolwell. *Teaching Environmental Studies*, Aylesbury: Ginn, 1978.

Lynch, K. *The Image of the City*. Harvard University Press and M.I.T. Press, Cambridge Mass, 1960.

Madders, M. Ecosystems in the Laboratory. *School Science Review*, Association for Science Education, Hatfield, 56, 197, 685, 1975.

Milgram, S. The Experience of Living in Cities. *Science*, 197, 1461–1468, 1970.

Patterson, M. Spatial Factors in Social Interactions. *Human Relations*, 21, 351-361, 1968.

Pollitt, E. and H. Ricciuti. Biological and Social Correlates of Stature Among Children in the Sleems of Lima, Peru. *American Journal of Orthopsychiatry*, 39, 735–747, 1969.

Reid, A.J. and N.J. Shaw. Environmental Education: Conceptual Approaches. *Primary Education*, East Melbourne, 65, 11, 1975.

Ricciuti, H.N. Panel Discussion: Social Environment, Learning and Behaviour. In *Malnutrition, Learning and Behaviour*, (eds.) N.S. Scrimshaw and J.E. Gordon. Cambridge, M.I.T. Press, 381–384, 1968.

Roos, P.D. Jurisdiction: An Ecological Concept. *Human Relations* 21, 75–84, 1968.

Santander, J. The Psychology of Protective Behaviour. *J. Safe. Res.*, 10, 58, 1975.

Scrimshaw, N.S. Malnutrition, Learning and Behaviour, *Journal of Clinical Nutrition*, 20, 493–502, 1967.

Sinha, S., S. Das and N.K. Jangira. *Environmental Education Module for Pre-service Training of Social Science Teachers and Supervisors for Secondary Schools*. Paris: UNESCO, 1985.

Sommer, R. Man's Proximate Environment. *Journal of Social Issues*. 22, 59–70, 1966.

Sommer, R. *Personal Space: The Behavioural Basis of Design*. Englewood Cliffs, N.J.: Prentice Hall, 1969.

Sommer, R. and F.D. Becker. Territorial Defence and the Good Neighbour. *Journal of Personality and Social Psychology*. 11, 85–92, 1969.

Strahler, A.H. and A.N. Strahler. *Geography and Man's Environment*. John Wiley, New York, 1977.

UNESCO. Needs and Priorities in Environmental Education: An International Survey, Intergovernmental Conferences on Environmental Education, Tbilisi, UNESCO/ENVED 6, 1977.

WER. *World Environment Report*, 6 Nos. 12, 13, 14, 1980.

Wheeler, K. The Genesis of Environmental Education. In *Insights into Environmental Education* (eds.) G.C. Martin and K. Wheeler, Oliver and Boyd, New York, 1975.

Wohlwill, J.F. The Physical Environment: A Problem for a Psychology of Stimulation: *Journal of Social Issues*, 22, 29–38, 1966.

Wohlwill, J.F. The Emerging Discipline of Environmental Psychology. *American Psychologist*, 25, 303–312, 1970.

21

Physiological and Medical Problems of Man Underwater

A.K. Chatterjee

Introduction

Due to physiological limitations man's unaided dive in water is restricted to less than a couple of minutes to a depth of 30 to 50 m. The AMA divers of Japan and Korea (traditional female skin divers), the pearl divers of Gujarat and Tamil Nadu and skin divers of Polynesia are still practising breath hold dives with great skill for gathering shell, sponge and pearl but not entirely without mishaps. The search for means to increase the depth and duration of dive has been on since ancient times. American Indians and Australian aborigines used reeds and bamboos as simple breathing tubes or snorkels for hunting wild ducks and fowls in water. In 1691 Edmund Halley, the famous astronomer patented the diving bell with air supplied from a barrel lowered in water. This made possible extended work for up to 1.5 hours at 20 metres for varied underwater jobs like salvage of ships, treasure hunts and construction works. With the development of the air pump, open helmets were introduced in diving where air under pressure was supplied to the diver in the helmet, which escaped from around the neck thereby keeping the water out with a fresh flow of air supply. The closed dress or standard diving rig was marketed by Augustus Siebe in 1837 giving a boost to safer diving at comparatively greater depth and longer duration. Decompression sickness, carbon-dioxide toxicity and nitrogen narcosis made their appearances and continued to haunt the divers. Fleuss introduced the oxygen re-breathing set in 1978 using ropes soaked in caustic soda for absorption of carbon dioxide. Then the problems of Hypoxia and oxygen toxicity came up. Paul Bert in 1878 concluded that decompression sickness is caused by bubbles and the pain is relieved by a return to higher pressure. He also elucidated the toxic effect of oxygen on the central nervous system causing convulsion at PO_2 in excess of 3 ATA. Lorraine Smith in 1899 demonstrated pulmonary toxicity caused by oxygen at a much lower PO_2 of 0.5 ATA (Atmosphere Absolute) but after long exposures. Haldane introduced the first diving tables in 1908. With slow staged decompression to the surface the dives became relatively free of incidence of bends. At the commencement of this century diving was limited to a depth of 30 to 50 m. With Halden's tables the depth quickly extended to 80 to 90 m where the narcotic affect of nitrogen showed up. Elihu Thompson suggested as early as 1919 that nitrogen narcosis could be avoided by the use of helium. The cost factor delayed its introduction ($ 2,000 for per cu foot at that time) Helium subsequently became cheap and its introduction took the divers to 130 m in water and 150 m in simulated condition in pressure chamber by 1930. Restricted availability of Helium prompted the search for another carrier gas for oxygen in diving. Hydrogen with 4 per cent or less oxygen to avoid explosion was used by Zetterstorm in the forties with success.

Helium extended the diving depth to over 500 m in water and 600 m in the compression chamber. But deeper dives involve very long unproductive decompression time for extremely short productive time at the bottom. This makes deep dives uneconomic particularly in the context of the growing need for diving in offshore ventures. Bond and Cousteau introduced the saturation diving techniques in sea lab and Conshelf experiments in early sixties to enable man to remain underwater for days and months.

Deep and saturation dives require extensive life support arrangements for the long duration of dive. Problem of heatloss, increased respiratory work from breathing dense gas, high pressure nervous syndrome becomes very important. These may become the ultimate limiting factors in extending the depth of the dive.

One atmosphere armoured diving suit has been developed to protect divers from the pressure at great depths. The problem here is the maintenance of the closed atmosphere.

Liquid breathing is still in the preliminary experimental stage but has showed some promise. Gas related major problems like decompression sickness and narcosis can be avoided if it is successful.

An artificial gill is also being conceived to extract oxygen from water and losing CO_2 from blood in direct exchange through semipermeable membranes. This is an interesting experiment trying to make a true 'Homo aquaticus' out of man.

Diving Marine Animals and Apnoeic Dive

Compared to man, diving mammals are remarkably adapted to marine environment. Stream lined shape and efficient propulsion allows dolphins to reach a 20 knot speed with the expenditure of 2 HP (1.5 KW) Ten times this energy will be needed to propel a similar sized object by mechanical means.

Certain anatomical and physiological adaptation allows the diving mammals to achieve great depths and stay there for long periods. Whalebone whales dive to 200 m, certain toothed whales to 400 m and sperm whales to 1000 m and can remain submerged for an hour or more. The pinnipeds (seals and otters) are comparatively shallow divers and remain underwater for less than a quarter of an hour at a time. However, weddel seals can dive to 600 m for a maximum of 1.2 hour.

In whales there is no sternum and the ribs are floating. The thoracic cage is not rigid and can partially collapse under pressure. The respiratory passage from the blow-hole to the lungs is short wide and tough. During diving the lungs can collapse almost completely. Air from the collapsed lung is accommodated in the dead space of the tough respiratory passage with no alveolo capillary exchange. The dangers of oxygen toxicity nitrogen narcosis or decompression sickness on subsequent surfacing are absent. The maximum depth reached in breath-hold dive is limited by the ratio of total lung volume to the residual volume. In an average man it is 4 : 1 (6 l : 1.50 l). In other words man can tolerate a pressure of 4 ATA which means can go to a depth of 30 m without suffering barotrauma. The record for breath-hold dive held by man is however 100 m. This was possible because of a high lung volume/residual volume ratio shift of blood volume in the thorax and reduction of thoracic volume by a raised diaphragm pushed by the abdominal visceras due to hydrostatic pressure. Exceeding the depth limit dictated by this thoracic squeeze cause pulmonary oedema, haemorrhage and ultimately collapse of the thoracic cage. It is evident that this ratio being very large in diving mammals they can go to greater depths compared to man's performance without being the victims of barotrauma.

Diving in marine mammals is accompanied by apnoea, bradycardia and peripheral vasoconstriction. In the weddel seal the heart rate falls from 55 to 15 per minute. Cardiac output from 40 to 6 l per minute but mean blood pressure is maintained at 120 torr which indicates extensive peripheral vasoconstriction. The circulatory adjustment causes a partial compartmentalization of central blood (about 8 l) and peripheral blood (52 l) more blood is diverted to the central organs like brain, heart and lungs to protect them against hypoxia. Blood volume and haematocrit is higher in diving mammals with smaller brain/body weight ratio and slower rate of metabolism in the brain. The net result is a greater oxygen reserve and less requirement allowing longer periods of submergence.

Mention must be made of the probable role of myoglobin in the muscles of these animals. Oxygen fixation in myoglobin could account for 50 per cent of the oxygen reserve available in diving. During apnoea due to muscular vasoconstriction the muscles use this source of oxygen almost exclusively.

During diving only the brain relies on blood glucose as a carbon energy source whereas the heart and lung preferentially appear to utilize lactate, thus minimizing its accumulation and sparing glucose for other tissues. In recovery all three organs accelerate the clearance of the post diving lactate in effect sparing glucose for subsequent diving.

During dive metabolites, carbon dioxide and lactic acid tend to be held in muscles due to low blood flow and venous return. At the end of the dive there is a reactive hyperaemia and a three fold increase in the blood lactic acid content. The Breaking point of breathing is delayed by the increased tolerance of the diving mammal as well as trained divers to CO_2.

Slow heart rate, peripheral vasoconstriction and minimal alveolo capillary gas exchange restricts nitrogen accumulation in the tissues. Post dive hyperaemia helps in quick elimination of tissue gases. Besides very high tidal volume assists in gas washout from the body. In turtles a shunt from right to left ventricle opens up during a dive allowing blood to avoid contact with high PN_2 in the lungs. Sea snakes can exchange gas through skins. Nitrogen absorbed through lungs is therefore lost directly into the sea and maintains an equilibrium with PN_2 of sea water (0.8 ATA). In diving mammals and other marine animals nitrogen accumulation in the tissues and subsequent bubble release during decompression are therefore prevented.

Heat is conducted through water 25 times faster than air. A thick subcutaneous layer of fat prevents heat loss in cold water in most marine animals. A New born seal and the polar bear have a thick fur layer. Peripheral vasoconstriation does not allow the surface cooling transmitted to the core.

It could be seen that the diving mammals and many other marine animals due to physiological and anatomical peculiarities are protected from barotrauma, decompression sickness, hypoxia, nitrogen narcosis and hypothermia, the usual complications that a diving man faces.

Such adaptations are unfortunately absent in man. Immersion bradycardia to a lesser degree is present in young divers while tolerance to hypercapnia is low. Tolerance can be improved by breath-hold training but may lead to dangerous hypoxia at the end of the dive by delaying the breaking point. This may be further compounded if the diver hyperventilates before a dive to reduce PCO_2 in the lungs. Even the most skilled diver cannot hold his breath for more than two to three minutes and go beyond 60 to 70 m. Artificial aids are threrefore needed to supplement the function of a human diver. Diving equipment and other supports allows man to come to terms with the watery environment. These aids allows man to dive deeper and longer but impose the need for physiological adaptation with the equipment and artificial gas mixtures that he breathes in addition to the adaptation that is required with the environment.

Diving with Equipment

Interaction of man, equipment and a watery environment is important to understand in support of life and work underwater. In the present discussion it is neither possible to encompass all aspects nor to go into sufficient details. Certain interesting topics will however, be briefly dealt with.

BUOYANCY

An average man is normally neutrally buoyant. The diver remains in a zero gravity situation in water. This may interfere with his sense of position. With a deep breath the chest volume will expand and will displace more water relative to his weight. The diver will be lighter and may float up unless weighted down or anchored with ropes. Conversely forcible expiration will make him negatively buoyant and make him go down. Advantage of this fact was taken in the thirties to train submariners to come up by free ascent from a sunken submarine.

VISION

Due to reflection on the surface, absorption in water and scattering of light by suspended particles the visibility will almost be nil by 90 to 100 m. In coastal turbid water the visibility may not be more than 10 to 20 m depth or even less. Differential absorption of the spectrum is marked underwater and in clear water red is so strongly absorbed relative to blue that by 30 m the whole environment takes a blue cast. However in coastal waters where the chlorophyll contained in phytoplankton and the yellow products of vegetable decay absorb light of short wavelength it is green and not blue which penetrates deepest.

The air space behind the visor doubly refracts the incoming light due to two interfaces, one with the sea and the other with the cornea. The objects appear bigger by one-fourth the size and closer by one-fourth the distance.

Field of vision is restricted to varied degrees due to various sizes and shapes of the goggles.

In water, the objects therefore are less visible, appear different in size and location and the colours are distorted.

VESTIBULAR FUNCTION

Auditory, visual and proprioceptive stimuli are frequently distorted underwater. Proper spatial orientation therefore depends more on vestibular input.

In the zero gravity watery media otolitic function could be distorted with confusion in the direction of up and down vector.

AUDITORY FUNCTION

In the absence of otologic barotrauma or decompression sickness cochlear functions show us significant change in deep diving. Depth related reversible conductive hearing loss may occur due to change of impedence in the middle ear on account of dense gas or change in resonance frequency due to helium.

AURAL BAROTRAUMA

The most frequent otologic problem in diving is aural barotrauma. This results from a pressure differential between the middle ear and the external environment and reflects the inability to equalize the pressure in the middle ear via the eustachian tube. Oedema, transudation and haemorrhage may occur in the middle ear sometime with rupture of the ear drum or round window. Rupture of the round window will precipitate sever and acute vertigo.

VERTIGO

Transient vertigo may occur due to unequal entry of cold water in the ear canal (differential caloric stimulation) unequal pressure equalization in the middle ear (alternobaric vertigo) and gas osmosis induced vestibular hydrop. Inner ear barotrauma and decompression sickness will cause vertigo of a more serious and lasting nature.

NOISE EXPOSURE

Noise levels in the recompression chamber and the helmet may be high leading to temporary auditory threshold shift. Possibility of permanent neurosensory deafness in divers exposed to excessive noise exists.

THERMAL PROBLEMS

Heat loss in water as well as hyperbaric gaseous environment is considerable.

The specific heat of water is 1000 times, heat conduction 25 times and convective character 167 times that of air (convective character of air is 1).

Convective character of helium is particularly high and is 185 for a helium oxygen atmosphere at 450 m (higher than that of water).

In the low temperature of deep water heat loss may amount to 300 to 500 kcal/sq m/h whereas the heat produced by the diver may not be more than 50/100 kcal/sq m/hr.

The entire metabolic heat generated by the body may not be able to compensate for the heat loss through respiration alone.

Thermal comfort zone at sea level is 20 to to 30°C, in oxyhelium atmosphere at 200 m it is 29 to 31°C and in water 32.5 to 34°C. The narrow thermal zone is difficult to maintain in an underwater habitat. Again because of reduction of metabolic heat production in sleep the comfortable thermal condition of working time may become unbearably cold during sleep.

Respiratory heat loss while breathing helium mixture may cause a feeling of chill even when a heated suit is worn. If the heating is increased due to sensation of cold the skin may be burnt.

RESPIRATION

Minor chest squeeze is experienced when breathing through a snorkel, at 80 mm (centre of chest at 8 cm depth) inspiration is difficult and fatigue supervenes. No inspiration is possible through a snorkel if the chest is at a depth exceeding 1.2 m. Respiratory resistance increases while breathing dense gas at high pressure. Breathing air at 30 m decrease MBC (Maximum Breathing Capacity) by 50 per cent. As depth decreases respiratory efficiency limits the work rate instead of cardiac output as is the case on the surface.

Equipment related respiratory resistance adds further to the work of breathing. Respiratory resistance can be reduced substantially by breathing heliox or hydrogen oxygen mixtures. Heliox and hydrogen oxygen mixture at 300 m have the density equivalent of air at 30 and 12 m respectively.

Liquid breathing (oxygen in water) increases respiration resistance 36 times that of breathing air on surface. The maximum possible pulmonary ventilation with water in man is less than 3.5 l. This is the basic requirement of alveolar ventilation at rest and will be unable to support consciousness even during moderate work.

Diffusion related hypoxia is another problem at depths. Oxygen cannot readily diffuse through the large mass of inert gas and the partial pressure is required to be raised to 0.4 to 0.45 for adequate oxygenation.

CARDIOVASCULAR FUNCTION

Bradycardia during breath holds, facial immersion and diving has been extensively studied. Its importance in apnoeic diving in man is doubtful.

Bradycardia without immersion has been observed during hyperbaric exposure in recompression chamber. Direct myocardial effect and increased vagal tone from PO_2 and nitrogen betablockade of the heart are considered the mechanisms responsible.

By keeping haemoglobin saturated, high PO_2 interferes with carbon dioxide elimination.

Cardiac arrythmia has been recorded in 60 to 70 per cent of AMA divers. This could be due to exposure to cold or hypoxia due to breath holding. Some physiologically interesting ECG changes have also been noticed in the compression which were possibly due to reduction of intestinal gas causing displacement of diaphragm and change in the heart's axis.

Immersion and cold diuresis particularly in helium atmosphere leads to reduction of blood volume and haemocentration.

High PO_2 may depress erythropoiesis. A 24 per cent decrease in erythrocyte count has been reported in Sealab II experiment where ambient oxygen ranged from 188 to 268 mm Hg.

Respiratory Gases

CARBON DIOXIDE

Carbon dioxide is of utmost importance to the diver. Most of the diving situation favours retention of carbon dioxide. Breathing dense gas or through masks tubings and valves increases the work of respiration. High PO_2 interferes with the elimination of CO_2, by saturating haemoglobin. Heat loss in water and helium dives demand increase in metabolism and formation of more CO_2. There is also the raised threshold of CO_2 tolerance in divers. This sometimes works against the diver's interest by delaying the warning signal of CO_2 retention.

Three tolerance limits for CO_2 are usually considered:

(a) 0.5 to 0.8 per cent usually cause no significant adaptive or physiological changes.

(b) 0.8 to 1.5 per cent do not effect basic physiological functions or performance but initiate long range adaptive changes.

(c) 3 per cent and above produce deterioration in performance and alterations in basic physiological functions.

Respiratory limitations association with oxyhelium and oxyhydrogen gas is found only at great depths and in association with heavy exercise. But with air because of its higher density reduction in ventilation during heavy exercise is observed even at 4 ATA.

Constant vigilance is required to be kept on the respiratory resistance produced by the diving sets. One way of checking it is to see whether blood PCO_2 level goes as high as 50 mm Hg while breathing through the set. But the general tendency of some divers to tolerate a threshold of CO_2 to 50 mm Hg even while breathing room air may not validate this test.

Living in saturation made in undersea habitat at 18 m has shown mild respiratory acidosis from the second week till the end of the experiment.

A 150 watt exercise load with 2 l/minute oxygen consumption was found to result in decrease in ventilation and CO_2 retention at 27 m.

High N_2 and CO_2 pressures were found additive in producing narcotic effect. CO_2 narcosis has been related to extra cellular pH.

CO_2 retention occurs frequently during exercise at high ambient pressure and is often the limiting factor in practical diving operation. CO_2 retention may occur even when the diver is hyper apnoeic. Hyperventilation increases oxygen consumption, metabolism, lactic acid production and sensitivity to stress and is to be consciously avoided in diving situation.

CO_2 and helium are known to cause great heat loss and have been implicated in fatal accidents that occurred in Sealab III and Johnson-Sea-link. CO_2 also enhances the toxic effect of O_2.

OXYGEN

Oxygen supports life at appropriate levels but is toxic in excess. Fire risk is an additional complication in its use.

Oxygen is the essential component of the breathing gas. Dizziness, euphoria and light-headedness is experienced when O_2 percentage is reduced suddenly from 21 to 15 per cent. Further reduction causes increased respiration, blurred or tunnel vision and motor impairment. Unconsciousness is likely to occur at 7 to 10 per cent. Reduction of percentage still further will cause death, usually at 3 to 6 per cent.

In closed circuit re-breathing set dilution hypoxia is one of the commonest incidences. At high pressure PO_2 is required to be raised to double that of normal air to maintain adequate oxygenation.

Short term exposures to PO_2 in excess of 3 ATA can cause epileptiform convulsions (CNS toxicity). Because of individual variation in susceptibility and augmenting effects of CO_2 accumulation and stress, not more than 1.7 to 2 ATA PO_2 is used in short term dividing.

Longer exposures at lower levels, perhaps 0.5 ATA and more for several hours may cause oxygen pneumonitis (Pulmonary toxicity).

Still longer exposures at still lower PO_2 will cause reduction in red blood cells.

The precise mechanism of O_2 toxicity is still unknown. O_2 acts at a great many sites on metabolic reactions or on specific cellular functions. Many enzymes have been found to be inactivated by oxygen *in vitro*. Enzymes containing sulpha hydryl groups are particularly susceptible. These include glyceraldehyde phosphate dehydrogenase (a key enzyme in glycolysis), the flavo protein enzymes of the respiratory chain and the enzymes involved in oxidative phosphorylation. Some metabolic effects of hyperoxia and radiation are similar and synergistic. Oxidizing radicals are found by high pressure oxygen and may be the real harmful agents in oxygen toxicity. Antioxidents glutathion and disulphiram afford some protection against hyperoxia.

There is reduction of Gamma Amino Butyric Acid (GABA) production. GABA is a transmitter at CNS inhibitory nerve synapses. GABA appears to protect against O_2 convulsion, so is lithium which is useful in treatment of manic depressive psychosis. Deficiency of GABA may allow uninhibited firing of excitatory impulses.

Formation of lipid peroxide disrupting cellular membrane may be the cause of damage in prolonged exposure.

Increased PCO_2 is also considered to be the cause of convulsion but is unlikely as the resultant increase in brain at 3 ATA small (2.5 to 6 mm Hg).

Action of inert gases is additive probably due to change in membrane conductivity and inhibition of polysynaptic pathways.

In pulmonary toxicity direct effect on pulmonary cell metabolism of enzymatic changes can be responsible. Atelectasis is common in oxygen breathing but inert gases which should prevent atelectasis actually enhances the toxicity. Disruption of surfactant activity by high PO_2 has also been implicated but is not conclusively proved.

Adrenelectomy and hypophysectomy protects against oxygen toxicity. ACTH and cortisone reverse this effect. Adrenergic blocking drugs reduce the damage.

High PCO_2 is concomitant to the toxicity but not the cause of it. The effects of PO_2 are however, aggravated by raised PCO_2.

CARRIER GASES

Oxygen becomes toxic when its partial pressure in breathing mixture exceeds certain limits. It must therefore be diluted with an inert gas. Nitrogen is an appropriate diluent for shallow dives and helium suitable for deeper dives. Neon and hydrogen are the other two alternatives for nitrogen and helium.

Nitrogen is the inert gas of choice for dives up to 60 m. Even at that depth nitrogen narcosis may cause enough deterioration of memory and mental capability to pose operational problems and impair judgement sufficient to become a serious safety hazard. The narcosis is aggravated by anxiety, cold, fatigue, sedatives and alcohol. It develops immediately on reaching depth and does not progress with time.

Mild impairment of performance and euphoria can be found at 2 to 4 ATA. Stupefaction and unconsciousness occurs at 10 ATA.

Depressant effects of nitrogen are revealed in the ECG as decrease in basal rythm and appearance of low voltage theta waves. Abolition of alpha blocking by mental activity is another effect of nitrogen narcosis.

High density causing increase in work of breathing and high solubility in tissues making its removal difficult from the tissues during decompression are other two unattractive properties of N_2.

Helium is light, easy to breathe, has a low solubility and is not narcotic. This is therefore the gas of choice for dives where nitrogen is unsuitable due to narcosis.

Among the problems with helium are distorted voice causing difficulty in communication, considerable heat loss from the body and high pressure nervous syndrome.

Helium causes high frequency squeaking voice which is difficult to understand. Special unscramblers are required to be used.

Thermal conductivity of helium is 6 times that of N_2. Considering that helium is used normally for deep dives where it is cold even in tropical waters the thermal problem is a serious one. Various methods of heating the suit and the breathing gas had to be devised.

High pressure nervous syndrome (HPNS) is noted in helium diving deeper than 150 m. The Central nervous system becomes hyper excitable with depression of neocortex. HPNS is characterized by appearance of tremor (8 to 12 Hz) loss of vigilance and microsleep, appearance of slow theta waves in EEG and dizziness nausea and vomiting. Its development is dependent on the rate of compression, absolute pressure and the nature of inert gas. Neon and helium do not appear to possess the narcotic properties of inert gases like nitrogen and hydrogen. They are likely on the other hand to cause HPNS. HPNS can be delayed or prevented by adding a narcotic gas like (N_2—He—O_2 mixture for very deep dives) or slowing the rate of compression. HPNS could be the limiting factor for very deep dives.

The mechanism is not very clear. Hydrostatic pressure perse, of O_2, CO_2, diluent gas, gas induced osmosis have all been implicated.

NEON

Neon like helium is inert and can be used as a carrier gas for oxygen. Neon causes less voice distortion and heat loss than helium. It is likely that neon will permit more rapid decompression from depth than helium. Neon does not cause narcosis or a decrease in mental or psychometric performance. Neon at depth will cause HPNS but tremor is less than that with helium.

HYDROGEN

Hydrogen with 4 to 5 per cent oxygen is safe to handle and can replace helium in deep diving. Hydrogen has 2 : 1 advantage over helium vis-a-vis pulmonary function. Voice distortion is similar, so is heat loss. Hydrogen has got some narcotic property but has advantage over helium in respect of HPNS.

DECOMPRESSION SICKNESS

Divers must breathe gases at raised pressure. During decompression the excess gas dissolved in the tissues must come out of the body without separation into the gas phase. Stage decompression (diving tables) allow elimination of the gas smoothly from the tissues via venous blood to the right side of the heart and then through lungs to the atmosphere. Inadequate decompression after a dive or exposure to high pressure will allow formation of bubbles and cause decompression sickness. Decompression sickness can manifest in itching of skin, pain in joints, paralysis, audiovestibular involvement, severe dyspnea, collapse and death. Vast majority of cases of decompression sickness is satisfactorily treated by recompression.

Mechanism of production of decompression sickness is still very incompletely understood. Gas saturation of tissues depends on blood perfusion and diffusion. With decompression nucleation of gas emboli occurs. The emboli may grow in favourable circumstances and cause damage by pressure or obstruction of blood flow. The emboli can get stabilized by acquiring a lipid, fibrin or platelet coat from blood and become resistant to dissolution.

REFERENCES

Benett, Peter. B. and H. David, Elliot. *The Physiology and Medicine of Diving*, 3rd ed., Bailliere and Tindal, London, p. 8, 1982.

Bert, Paul. *Barometric Pressure* (1878). Trans in English by Hitchcock and Hitchcock (1943) republished by Undersea Medical Society, Inc., Bethesda, Maryland, pp. 709–751, 1978.

Davis, R.W. *Deep Diving and Submarine Operations*, 7th Ed., Siebe Gorman Chesington Surgery, 1962.

Dugan, J. *Man Under the Sea*, Coller McMillan, New York, 1965.

Edmonds Carl, Christopher Lowry and John Pannefather. *Diving and Subaquatic Medicine*, 2nd Ed. Diving Medical Centre, New South Wales, Australia, 1983.

Halley, E. The Art of Living Under Water, *Phil. Trans. Royal. Soc. London* 29: 492–499, 1716.

Miles Stanley and D.E. Mackay. *Under Water Medicine*, 4th Ed., Adlard Coles Ltd., London, pp. 96, 163, 1976.

Opermann, K.E., Jr. Man's Early Attempts at Underwater Diving, *Proceedings of the 8th International Conference on Underwater Education*, National Association of Underwater Instructors, Colton, California, pp. 229–250, 1976.

VI

ENERGY AND ENGINEERING SCIENCES

22

Energy in the World

Hermann Bondi

To begin, it might be useful to give some figures for energy consumption per head of population in different parts of the world. Since I am most familiar with the kilowatt as an energy unit I will talk about kilowatts.

In North America energy consumption per head is about 8 kilowatts throughout the year. In the other industrialized countries the figure is in the range of 2.5 to 4.5 kW per head, and in the oil-rich developing countries such as Saudi Arabia and Iraq the figure is in the region of 1 kW per head. In the oil-poor countries of the developing world, however, a figure of 250 watts per head might be a fair estimate, although we have no reliable figures. The reason for this is that in the industrialized world energy is commercial energy: you buy it, pay for it, and when you receive the bills you have no doubt that it is commercial energy. But in the poorest countries of the world energy comes from firewood, dried dung, etc. No money changes hands; you just put your own labour and time into gathering fuel.

The heat output of human beings varies from around 100 watts when we are sleeping to around a kilowatt and a half during the most energetic exercise, averaging out at perhaps 150 watts over the day. Every human being clearly requires an equivalent intake if he is not to die of starvation. Thus, the amount of energy that we require from food is 150 watts or so, and is a negligible part of the total consumption per head in an industrialized country, but a dominant part in the poorest countries. In the poorest countries the residual amount of energy consumption is largely accounted for by cooking, albeit at a minimal level; in the industrialized countries the situation is of course much more complex. Generally speaking, 40 per cent or so is used domestically for heating, hot water, cooking, lighting and refrigeration. Industrial purposes account for 40 per cent and transport for 20 per cent. These figures may be a bit arbitrary, since for example they count as domestic the gas or electricity used for home cooking, but as industrial the energy that goes into making a cooker. They count as transport the fuel used by cars, but as industrial the energy that went into making those cars. However, such divisions do at least enable us to draw some generalized conclusions about energy consumption.

During the fifties and sixties there was a strong correlation between the growth rates of economies and the consumption of energy. With all the turmoil and depression of the last ten years the situation is now somewhat different, but, if one is still able to be optimistic, then one would like a resumption of growth in gross national product.

The gross national product, although it is an aggregate of many different activities, is not a perfect measure. One may, for example, grow vegetables and consequently eat both a larger quantity and better quality of vegetables without paying for them. But, as they are not actually bought and paid for, such home-grown vegetables make a smaller contribution to the gross national product than those which are bought and paid for, although they are actually responsible for an increase in the standard of living. In the strictest sense, therefore, the gross national product is not directly a measure of national well-being, or even of prosperity. It is nevertheless a reasonable measure acceptable for broad comparison.

One can look at different activities and ask how much they contribute to the gross national product, how much energy they consume and how they compare with other activities. The comparisons may not be exact but they at least give us useful indications.

The main point of interest is the relationship between energy consumption and well-being. It may be that some activities demand a high energy input and contribute very little to well-being; some may contribute a lot for a low energy input. When using the gross national product to assess this relationship we need to consider how much energy is needed in each case to generate a certain contribution to the gross national product.

A surprising illustration of this is provided by water transport, which is actually more energy intensive than transport by air. Because the convenience of despatching goods by air is so great one is prepared to pay much more for it, and it therefore contributes much more to the national turnover, outweighing even the difference in energy consumption between the two modes of transport. Air transport therefore makes lesser demands on national energy consumption per 100 dollars value added than does water transport.

In the energy intensive activities, which need a great deal of energy to add to the gross national product, we can include the manufacture of steel, aluminium, heavy chemicals, etc. In terms of energy non-intensive activities, which add a great deal with a relatively small energy input, we have financial services, education, telecommunications, entertainment, television, leisure services and so on. Between the two extremes one finds a difference in energy consumption of about a factor of 10. This ratio is not much larger than this because even with financial services, buildings still have to be heated and lighted and people consume energy in travelling to work. So, energy consumption is not negligible by any means, although it is markedly less than it is in the energy intensive industries.

I believe that most of us think that renewed prosperity will especially lead to an increase in the energy non-intensive activities such as those I have mentioned. But we do not, I think, believe that future prosperity will mean vast expansion in steel, aluminium or heavy chemicals. (I think that relatively few people enjoy driving two motor cars at once!).

A further reason why development and prosperity in industrialized countries should not lead to increased energy demand lies in increasingly efficient control of energy usage. Our cars, for example, are much more efficient now than they were ten years ago; our heating is more efficient too. The amount of primary energy used in this country for domestic space and water heating is in fact the same today as it was 60 years ago—60 years which have seen an appreciable growth in the population, a vast improvement in housing, an increase in space per head of the population and an unbelievable improvement in comfort.

Improvements in our standard of living need not, therefore, mean a growth in energy consumption and I am convinced that we can go much further in this direction. I particularly feel that we are still at the very beginning of using controls to our best advantage.

In the poorer parts of the world, however, the situation is totally different. In these countries the most appalling thing is that if the weather is a little more fickle than usual, malnutrition and death from starvation, become common. What is needed is an acceptable standard of living without fear of malnutrition or starvation and in order to achieve this we must think in terms of irrigation, transport and storage of food, refrigeration and fertilizers (and therefore heavy chemicals). I should like to stress the importance of transport and storage in particular. When, about ten years ago, the Indian monsoon failed on successive occasions, the rest of the world supplied a great deal of food to relieve the threat of starvation. This food got to the ports and to many people in the cities, but distribution to the desparately poor country areas was hopelessly inadequate. (A sizeable fraction of what eventually did reach these areas was eaten by rats because of poor storage facilities!). But, when almost simultaneously the Soviet Union was forced to buy large amounts of food because of poor harvests, distribution and storage of the food did not present even the slightest problem.

In the poorer parts of the world, therefore, apart from energy to increase indigenous food production in the form of fertilizers and irrigation, it will be necessary to have railways and roads, refrigeration (rat proof silos!), and so on. These are all immensely energy intensive.

So, if we see economic growth in the industrialized countries, and at the very least the banishment of starvation from the poor countries, as desirable aims, then we must think in terms of a very minor increase, if any, in energy consumption in the industrialized world, but a very considerable increase in energy consumption in the developing world. This will mean a moderate increase both in terms of consumption per head in developing countries and, because there are so many heads there, a great increase in total consumption.

If this increase is to be met we need to consider which energy sources should, or even can, meet this increase. Oil quite clearly has enormous advantages—we understand it very well, we can refine it into tailor-made fuels packed with energy per unit volume. It is easily and very cheaply transported over global distances. However, oil reserves are actually very limited and while production can still rise somewhat it will peak in the not very distant future and then either level out or decrease. The relationships between price and availability are very complicated. We must consider questions such as, how small a reservoir is worth exploiting? How awkward a geographical area is worth exploiting? But I think it is clear that oil is unlikely to be able to take the strain of a major increase in world energy consumption.

Gas also has many advantages—it is a singularly clean fuel, and its reserves are likely to be larger than those of oil. But it also has a major disadvantage in that it is hard to transport over great distances, and for this reason a huge amount has to be flared off every day in the Middle East because it cannot be transported at an economic rate. So, while gas undoubtedly has great use, we cannot, I think, expect it to take the main strain.

Coal is, of course, an enormous reservoir. Whether it lasts 150 or 450 years, there is undoubtedly plenty of coal around, in very large quantities and in very many places. Coal, however, has two or three drawbacks. Firstly, it is expensive to transport when compared with oil, and indeed in almost every way coal suffers from the fact that our technology for handling solids is not nearly as advanced as our technology for handling liquids. Secondly, whereas the refining of oil is very well developed, the refining of coal on the industrial scale is still a task for the future. I am sure that it is a task that we can accomplish, but there are still important questions of efficiency, cost and, not least, end product, to be answered. Another important point is that although coal is distributed widely, the three biggest countries, the United States, the USSR, and China, have about 85 per cent of the known reserves between them. This is perhaps a slight worry, even if some of the coal in these countries is rather more expensive coal to gain than that elsewhere. A few other countries such as the UK and Germany do have plentiful indigenous supplies, and these can be counted as fortunate. In spite of its disadvantages, however, if there is to be an increase in world energy consumption then there is certain to be a vast increase not only in the mining of coal, but in its transport and distribution.

Let us now consider nuclear energy. We all know we have problems with nuclear energy. Broadly speaking, it is not liked by the mass of the population. I do not intend to enter here into the reasons whether this dislike is or is not reasonable. The mere fact that it exists is a fact with which we have to live. Nuclear energy is also limited to the production of electricity which, while it can be cheap and can supply a good deal of energy, cannot be more than a proportion of the total energy demand.

Furthermore, nuclear energy as we currently produce it relies on the world's somewhat limited uranium resources; somewhat limited, that is, as regards rich ores. We know, however, that in the long term we can get about 70 times more energy from uranium by using breeder reactors than we do using our present type of reactor. An increase of this magnitude will mean that our uranium reserves are actually large even when compared with the scale of coal reserves. Breeder reactors are, however, still a long term consideration, especially as regards their economic performance.

Fusion energy, it is often thought, offers a prospect of an unlimited source of energy with none of the disadvantages of nuclear power. This is, however, quite untrue. Fusion power also produces radioactive nuclear waste (though perhaps rather less than fission reactors), has the additional hazard of tritium, is as least as highly centralized, and is dependent on lithium reserves. I see no advantage in fusion power over breeder reactors, whose development is much further advanced.

Finally, renewable or semi-renewable energies have an important part to play. For convenience I make a division between intermittent or continuous energy sources. By intermittent I mean solar energy, wind energy and so on, where we cannot guarantee that the sun will shine or that the wind will blow all day long. If we consider using solar energy to pump water in an irrigation scheme, then it is not crucial whether you pump water at night or during the day. Of course, there are many drawbacks to intermittent energy sources, and we cannot expect them to carry part of our base-load electricity demand, but these energies can be important in particular circumstances.

Another potentially important energy source is geothermal energy. Temperature increases with depth, although the temperature at any given depth may vary according to the flow of the earth's radioactive heat through any particular place and according to the constitution of the rocks you are drilling. There are essentially two ways of producing geothermal energy—one well-established and the other under development. The established method is to drill into a layer of water-filled porous rock which is contained within impermeable rocks. This water will have been heated by the surrounding rock and can then, provided there is sufficient flow through the rock, be pumped up and used. Its usage will depend on its temperature. If, for example, it is at

75°C it could be useful for space and water heating, but would not enable economical electricity production. If it was at 130°C, however, electricity production could be worthwhile.

The other possibility for geothermal energy is to drill into a dry rock and pump water down the drill hole so that it will be heated by the rock, and can be pumped up again as hot water. Unfortunately, the water rapidly cools the rock, and after about a week it will not be sufficiently hot to be of use. Naturally, the rock will regain its lost heat, but as the conductivity of rock is rather low this may take 15 years or so.

The method now under development utilizes a large volume of rock by creating lots of hairline cracks so that the water, or other liquid, pumped into the rock will have a much greater surface area of rock to heat it. In this way the rock could be cooled gradually, over perhaps 20 years, making it comparable to an oil well or coal mine.

There will never be an absolute shortage of energy. If one is prepared to pay enough for it, it will always be available. However, the price of conventional energy today means that the energy crisis is not something for the future, but is actually here now in many parts of the world. There are places where the rise in the price of oil has driven the populations back to using firewood, destroying forests and turning whole areas to desert in the process.

The central question, of the price of energy, is equally relevant to all current and potential forms of energy. I must say here that I detest the expression alternative energy. It is not a question of alternatives, but of grabbing everything we can. To say, for example, that there is a choice between nuclear and wind power is nonsense—both will be required if we want energy at a price that is affordable in the developing world.

The issue which I see as central to energy and its future is the effect of the industrialized countries' usage of energy upon the ability of the poorer countries to buy the energy they need. If in an industrialized country we choose not to use some source of energy, be it nuclear energy or coal under beautiful countryside, then we will have to use more oil instead. Thus we will reduce the availability of oil and increase its cost, which is a minor problem for us but a disaster for the poorest countries. Yet we in the industrialized world are so inward looking that this aspect of our energy decisions is hardly ever mentioned, though it is of profound significance for the developing world.

23

New Energy Technologies for Entering the Twenty-first Century

Maheshwar Dayal

The focal theme of this Session of the Indian Science Congress namely 'Science and Technology in Environmental Management' is an extremely relevant and topical subject. For all its resilience, life on earth is sustained by physical and chemical parameters within fairly narrow limits. These limits are even narrower in the case of human species. For mankind to survive on this planet, it is necessary to maintain environmental factors such as atmospheric temperature, quality of air, water and soil within certain limits. Today mankind's development is threatening its own survival in some ways. The industrial civilization, if not properly guided, has the potential of destroying in a few centuries not only the human species but a whole range of life-forms which have taken millions of years to evolve.

The cumulative actions of a world population approaching 5 billion are now capable of causing continental and even global changes in natural systems, according to the State of World 1985, a Worldwatch Institute report on "Progress toward a sustainable society". As human pressures on the economy's natural support systems increase, the more severely stressed ones are beginning to break down. Nowhere is this more tragically evident than in Africa, where famine is spreading across the continent. As recently as 1970 Africa was essentially self-sufficient in food. In 1984 however some 140 million Africans out of a total of 531 million were fed with grain from abroad. Acid rain and air pollutants from the combustion of fossil fuels in automobilies and power plants are laying waste the forests of Central Europe. Indeed pollutants may be destroying the forests of Czechoslovakia, Poland and West Germany even faster than the axe and plough have destroyed those of India and El Salvador. The loss of forests is not the only unforeseen cost of the growing use of fossil fuels. The report describes levels of carbon dioxide and other 'greenhouse gases' released to the atmosphere as likely to cause climatic shifts that would disrupt food production, reduce dependable water supplies and eventually jeopardize coastal cities and towns. Shifts in rainfall are closely associated with a rise in average temperature caused by rising atmospheric carbon dioxide levels and deforestation.

Energy is one of the key factors affecting the economics and social development of mankind. The rate and pattern of energy consumption today are both the cause and the result of the economic development which has taken place in the last couple of centuries. The invention of the steam engine, discovery of oil and the ability to harness nuclear energy are some of the landmarks in human history which have changed the life styles and perceptions of vast segments of the earth's population. The growing population and the natural needs of development of economically developing countries will inevitably require increasing energy supplies. Besides leading to depletion of limited resources, this trend also has environmental implications. It is therefore necessary for policy makers, scientists, technologists and economists to evolve strategies which can be applied on a global scale for a balanced exploitation of energy resources and equitable distribution of benefits which energy can bring.

One of the problems that cannot wait too long is the question of depleting oil resources. Though additional sources are being discovered and newer technologies developed for enhanced recovery, it is clear that availability of oil and natural gas will diminish rapidly in the 21st century. In fact, recent calculations of the resources to production ratio in respect of crude oil indicate that India has resources of only 17 years at current levels of production. The global average is 34 years. Thus, the present international economy, which is dependent heavily on hydrocarbon energy sources, will have to shift to a new energy base. This transition, inevitable as it will be, is not necessarily a freightening problem. Thanks to world-wide efforts made during the last few decades, it appears that we might be able to develop technologies and apply them on a large scale to ensure a smooth and harmonious transition. Energy is unlikely to be ever as cheap as it was in the early seventies. But the international economy will probably adjust itself to this situation. On the positive side, the transition may lead to application of environmentally sound technologies which will not only make available adequate supplies of energy but also ensure that mankind's fragile environment.

While energy is an issue of global concern, I would like to concentrate more on the situation in India as it is a subject of great importance for a developing society like ours. The need for increasing the supplies of energy in various forms like coal, oil and electricity was recognized by our planners and leaders nearly four decades ago. As a result we have today an impressive, though perhaps still inadequate, infrastructure for the production and distribution of energy. The successive development plans have necessarily required increasing consumption of energy. These trends have been analysed in detailed studies. The consumption patterns of commercial and non-commercial energy sources and projections up to the year 2000 are given in Table 1.

TABLE 1

Consumption of commercial and non-commercial sources of energy – trends and projections

(In millions tonnes of coal replacement)

Year/Sources	Commercial Energy	Non-Commercial Energy	Total
1953–54	60.4	125.9	186.3
1960–61	101.2	145.5	246.7
1965–66	147.0	159.6	306.6
1970–71	197.3	172.2	369.5
1975–76	252.7	194.6	447.3
1982–83	390.2	204.1	594.3
1987–88	539.8	202.8	742.6
1992–93	759.2	195.8	955.0
2000–01	1261.3	163.5	1424.8

Source: Report of the Working Group on Energy Policy, Planning Commission, Government of India (1979).

The main features that emerge from this analysis are that total energy consumption per year in India is likely to exceed 1400 million tonnes of coal replacement with the share of commercial energy sources being as high as 88 per cent. In physical terms, this implies an annual requirement of about 531 million tonnes of coal and 92.7 million tonnes of oil by the turn of the century. On the electrical side, the country may need over 500 billion kWh in the year 2004–05 with a total installed capacity of at least 150,000 MW. These figures should be compared with the present levels of production of about 150 million tonnes of coal and lignite, 26 million tonnes of crude oil, 150 billion kWh of electricity and a capacity of 43000 MW. Even if the figures for energy demand at the beginning of the twenty-first century are reduced somewhat by improving the efficiency of utilization and better demand management, it is clear that gigantic efforts will be needed to organize the production, transportation, refining and distribution of such quantities of fossil fuels and for generating and transmitting such levels of power.

Even if resources are somehow made available and production of fossil fuels and generation of electricity stepped up sharply, it should be clear that this will not be without its costs in environmental terms. The following are some of the likely consequences of these measures:

1) Coal mining, particularly opencast mining on an extensive scale is likely to cause serious damage to the landscape and vegetation around the mine-sites. The washing and processing of large quantities of coal can also cause serious atmospheric and water pollution.

2) Atmospheric pollution from thermal power plants could become a common feature and the country faced with problems like acid rain. Potential damage to the environment in areas with a high concentration of thermal power stations such as Singrauli area of Uttar Pradesh is already a matter of serious concern.

3) A significant expansion of the nuclear power generation programme raises unavoidable problems relating to radioactive material handling, waste disposal and decommissioning of plants.

4) A high consumption of petroleum products will also lead to an adverse environmental impact particularly in urban centres and around gas fields and oil refineries.

One other consideration to be kept in mind in evolving a long-term energy strategy is the energy requirement in rural areas. It is estimated that the rural population would still constitute about 70 per cent of the total population by the turn of the century. The developmental needs and hence the energy requirement of this large segment will naturally have to be provided for in an optimal fashion. There were about 200,000 villages to be electrified at the start of the Seventh Plan; about 100,000 of these are likely to be electrified by 1990. It is estimated that there are about 90,000 villages in desert, hilly, forest and backward areas of which at least 10,000 would be in difficult and isolated locations. These villages can be more economically served by decentralised energy systems using renewable energy sources. It is anticipated that using a combination of conventional and non-conventional energy supply systems, every village in India would be electrified by the turn of the century. This however does not imply a solution to rural energy problems. For, as experience has shown, the provision of a powerline does not ensure continuous availability of electricity; further only about 14 per cent of all households even in electrified villages actually have electricity connections. Given the fact that the per capita useful energy consumed per day in rural areas is about 285 kcal compared to 414 kcal in urban areas it is clear that we have a long way to go in enhancing energy supplies in rural areas both for household and agricultural and other economic applications.

New and Renewable Sources of Energy

It is now increasingly realised that renewable energy sources will have to be developed in India in order to reduce the dependence on oil and for promoting decentralized energy supply and consumption. Research and development efforts have started yielding results during the Sixth Plan. In 1981 a Commission for Additional Sources of Energy was set up by the government in order to coordinate and formulate policies and programmes for the development of new and renewable sources of energy. A separate Department of Non-Conventional Energy Sources was established in 1982 to implement the programmes approved by the Commission. The Department is implementing a wide ranging programme of research, development, demonstration, utilization and awareness promotion relating to a number of renewable energy technologies. Among the areas covered are solar energy, wind energy, biogas, biomass, hydro power, urban wastes, MHD, Hydrogen and other chemical sources of energy, geothermal energy and ocean energy. The developments in these areas and the contributions presently being made to the national energy scene are summarized below:

1) *Biogas:* India is one of the pioneering countries in the development and utilization of biogass from animal wastes. The advantages of this technology are well-known. The generation of gaseous fuel from animal dung through anaerobic digestion leads to improved sanitary conditions, availability of a clean fuel for cooking, lighting and even for running engines, reduction of drudgery and improved health conditions for women. Both fixed and floating dome type digesters are being propagated in India through a programme of subsidy and training. As against 25,369 plants built during 1981–82, as many as 180,430 plants were built during 1984–85. The progress over the last decade is given in Table 2. An aggregate of 457,100 plants were built over the last decade leading to significant savings in wood or other fuels. It is estimated that fuel equivalent to about 1.7 million tonnes of firewood is being saved annually, thus reducing the pressure on forests.

TABLE 2

Installation of biogas plants in India

Year	No. of plants installed
1974–75	10710
1975–76	14322
1976–77	14228
1977–78	16261
1978–79	14756
1979–80	15506
1980–81	15430
1981–82	25369
1982–83	57498
1983–84	92950
1984–85	180430
	Total: 457100

Another important innovation made in India relates to the use of community-size digesters. Such digesters are generally in the sizes of 45–80 cu m and are of the floating dome model. Over 100 such plants have been set up in different parts of the country and are providing cooking fuel to 60 to 100 families in each community. Some plants are attached to institutions such as dairy units and cattle farms. Part of the gas generated is also being used for electricity generation at some places.

2) *Biomass:* Biomass in the sense of fuel from trees and agricultural wastes is perhaps the most important renewable source of energy in India. A large portion of the cooking energy needs is still met from fuelwood leading to constantly increasing pressure on forests. One way to reduce this pressure is to improve the efficiency of wood burning. With this objective in view, the Department of Non-Conventional Energy Sources has developed a programme for the demonstration and popularization of improved woodstoves which are two to three times as efficient as older designs. Several new designs of such woodstoves were evaluated and brought under a scheme of subsidy and promotion. A number of training courses in the fabrication of such stoves have been organized as part of this programme. A total of about 900,000 stoves have been supplied or constructed so far. Besides saving hunderds of thousands of tonnes of fuelwood, these stoves are also contributing to improvement of the health of rural women on account of greatly reduced smoke in homes.

Another attractive application of biomass in Indian conditions is the generation of electricity using agricultural resides such as rice straw and bagasse or through energy plantations. New technologies such as fluidized bed boilers, predrying of agricultural residues and gasifiers can be effectively used here. It is estimated that an energy plantation-cum-power project can help to generate 3 MW of power from 1000 ha of land. The plantation can be grown on wasteland, or other non-agricultural land. Further, a project of this type can provide cooking fuel for 125 to 150 families besides generating significant local employment. Such projects can be taken up in a decentralized manner, thus spreading the benefits of employment and energy over vast areas. Some projects have already been initiated in India.

3) *Solar Thermal Energy:* Solar thermal energy utilizes heat energy from sun for meeting various energy requirements, particularly those of low and medium grade heat. As a result of research and development efforts in the country, several devices and systems have been developed and brought to the stage of commercial utilization. These include solar water heaters, solar driers, timber kilns, solar cookers and solar stills. Solar cookers are being manufactured on a commercial scale and made available through a programme of subsidy in almost all states. Over 35,000 cookers have been supplied under this programme. The drying of agricultural products as well as timber using solar energy has already been successfully demonstrated and is

being applied on a wider scale. Use of solar energy for water heating is spreading rapidly and is beginning to make an impact on consumption of conventional fuels, in establishments such as hotels, hospitals, dairies, textile mills and food processing industries. Solar thermal power generation is being attempted on an experimental basis and the first such plant for villages is nearing completion at Salojipally village in Andhra Pradesh.

The application of solar energy for thermal purposes has already started on extension basis in India. Research and development efforts are also being accelerated by several scientific groups in India to further improve efficiencies, reduced cost and develop newer materials. These efforts need to be intensified. At the same time greater effort is needed for developing a cooling system based on solar energy. These applications are of particular interest to India and other developing countries. Developing economical methods for such applications can place India in the forefront of a technology with near revolutionary significance.

4) *Solar Photovoltaic:* The direct conversion of sunlight into electricity with no moving parts and high reliability makes solar photovoltaics (PV) a very attractive renewable energy technology for developing countries like India. The features and advantages of PV systems make them ideal for remote and isolated locations and in non-electrified rural areas. Their present high cost limits their application to places where the requirement of power is not high. Among the applications which have been successfully demonstrated are water pumping for irrigation and drinking water supply, street lighting, community television sets, lighting of community buildings, medical refrigerators and battery charging for communications. About 1500 solar powered devices are today providing benefits of electricity—even if to a limited extent —in about 160 villages in different parts of the country. These are proving to be a great benefit in non-electrified areas, many of which are inhabited by tribal and other backward sections of the society. Two villages have been provided with 'Central' PV power systems. Several more systems ranging from capacity of a few kW to about 20 kW are also being planned.

Among the scientific developments in India of interest to the photovoltaic community is the development of indigenous technology for the production of high grade silicon required for PV device manufacture. With this the country can be self-sufficient in silicon supplies for this important programme. Among various technological programmes being pursued by the DNES are the development of polycrystalline silicon technology, amorphous silicon solar cell technology and photoelectrochemical cells. In fact the amorphous silicon area has been identified as one of the Science and Technology Missions of the country for the Seventh Plan.

5) *Wind Energy:* Wind energy can be used for water pumping, battery charging and power generation applications. Several hundred water pumping wind mills have been installed for the purposes of field trial and demon-

stration and these are now available for individual users at subsidized prices. While they are most advantageous in areas where the wind regime matches the water requirements, they also serve the useful purpose of reducing diesel consumption. Five wind farms are being set up in the country to produce over 3 MW of power to be fed into the grid. Several battery charging units in the kW range are also being installed; these can function in the stand-alone mode and meet the electrical energy requirements of rural communities. It is estimated that Gujarat state alone has potential of generating 5000 MW of electrical power from wind energy.

6) *Small Hydro Power:* Hydro Power has long been regarded as a renewable energy source which is non-polluting and providing electricity at the lowest cost. However, most of the untapped potential in India is in difficult terrain or at a distance from major load centres. The capital costs of large dams have also been increasing substantially in recent years. The cost per MW of power has gone up significantly from Rs. 24 lakhs in the First Plan to Rs. 171 lakhs in 1984–85 at the end of the Sixth Plan. The possibility of using small hydro power sources such as low-head and canal drops has attracted considerable interest in recent years. In the Himalayan region, hydro energy has also been used for stationary motive power applications. The DNES is supporting research and development and demonstration projects based on newer techniques of utilizing hydro power.

7) *Urban Wastes:* The disposal of wastes is becoming a severe problem in several of our urban centres. It is now possible to generate energy using such wastes and in the process also mitigating the environmental problems of urban areas. The gas generated from treatment of sewage is already being used as cooking fuel in several hundred households in Delhi. Another project in Delhi seeks to generate about 3.7 MW of electricity through incineration of solid wastes. Pyrolysis of wastes is also being pursued on an experimental basis. The programme for cleaning the Ganga also envisages the establishment of waste treatment plants at several points where significant quantities of energy can be generated.

Technologies for the Twenty-first Century

It will be seen from the foregoing that renewable energy technologies have begun to make an impact on domestic and rural energy supplies, and are poised for significant further development and application. These technologies are basically conducive to the preservation and even improvement of the environment. One of the principal problems associated with these technologies is the relatively higher initial cost of systems which inhabits individual users. However, in most cases, the savings in the running costs of renewable energy systems pays back adequately. What is needed therefore is an innovative package of financing supported by a country-wide network for the manufacture, distribution and servicing of renewable energy products. Significant research and development would still be needed to bring down costs and improve the performance and reliability of the systems.

While a whole range of energy requirements can be met through renewable sources, it must be remembered that the country has a great variety of energy demand situations, some of which cannot be met through decentralized options. We will therefore continue to need bulk power generation arrangements as well as large facilities for extraction and processing of fossil fuels. What is needed however is a clear understanding of the roles of different energy sources in our national economy, and a balanced development which can sustain economic growth as well as preserve the environment. This will imply newer technologies to be used increasingly even in the conventional energy sector.

It is fascinating to attempt a forecast of the type of technologies which will serve the country in the next century. Long-term forecasts are generally based on present trends and expectations and on the present level of knowledge; therefore they do not necessarily turn out to be accurate in all respects. Subject to this caution, I would like to mention a few energy technologies which could be relevant for us in the twenty-first century.

1) *Nuclear Energy:* If the present plans are fully implemented, the country will have an electrical generating capacity of 10,000 MW based on nuclear energy by the turn of the country. These power stations would be based on the presently known technology for using natural uranium and heavy water reactors. The country's first experimental Fast Breeder reactor has recently been commissioned. However full scale commercial fast breeder reactors are unlikely to be available during the next two decades. When these are developed the country can look forward to using its abundant thorium reserves. Another nuclear technology of perhaps even longer term significance is fusion. It may be another quarter century before fusion technology becomes commercially available. At this stage, it is difficult to estimate the costs of new power stations based on fast breeder reactors or fusion reactors. Suffice to say that due to a host of safety, environmental and technological considerations, the cost of such stations could be significantly higher than coal-based units.

2) *Coal Technologies:* The country has good reserves of coal and it would be appropriate to develop suitable technologies for better utilization of this important energy source. The country will need improved mining techniques as well as newer methods of transportation of coal. Gasification of coal and fluidized bed combustion are the two technologies which if seriously pursued, could be effectively utilized in the twenty-first century.

3) *MHD Power Generation: Magnetohydrodynamic* power generation technique enables the direct conversion of heat into electricity. The first experimental plant using this technology in the country was commissioned in 1985. After a period of experimentation and learning we could consider retro-

fitting an existing thermal power station with an MHD unit and eventually establishing a 400 to 500 MW plant combining MHD and conventional power systems. The overall efficiency of energy conversion in such plants could be as high as 60 per cent compared to less than 40 per cent achieved in conventional plants today. This technology thus has a significant potential for reducing the consumption of coal per unit electricity generated; in the process MHD plants also place less demands on cooling water and result in lower levels of environmental pollution. One important snag here, however is the need to develop and operate sufficiently large super-conducting magnets needed for generating power at these levels. Other related investigations pertaining to materials, plasma handling and diagonostic systems are also needed.

4) *Solar Energy:* It is anticipated that PV conversion devices based on single crystal or polycrystalline silicon would have been optimized by 1990 with the actual costs reaching the levels of $ 2 to 3 per peak Watt. While efforts on other materials such as gallium arsenide as well as concentrating systems will no doubt continue to be made, it is generally expected that thin film solar cells will lead to lower costs. Amorphous silicon solar cell technology has been shown to be particularly promising and cost levels less than $ 2 or even $ 1 peak Watt have been projected for the nineties. Multi-layer cells capable of using several wave-lengths of visible spectrum could become technologically mature by the year 2000. If these projections materialize, it can be anticipated that the PV market in the country will expand very significantly, perhaps to a level of 100 MW per year by the end of this century. One can visualize a large number of grid-connected and stand—alone power generating stations utilizing solar energy by that time.

Solar energy will also able to supply electric power on a large scale through the thermal route. Megawatt size solar thermal stations have already started operating, and with the advent of more economic materials, as also sterling engines, several designs of solar thermal power stations are likely to become economical, and it should be possible to use this technology on a much wider scale for industrial process heat as well as domestic requirements.

5) *Biomass:* The possibility of generating power using energy plantations and gasifiers has already been mentioned. It should be possible for the country to embark on a larger programme which envisages utilization of wastelands for growing high yielding and fast maturing species. Scientific research relating to tissue culture and genetic engineering are likely to give us the required break-throughs in this field. There is however clearly a social dimension to this programme which requires a harmonious relationship between man and forest. Another set of technologies relating to biomass utilization relates to the conversion of biomass into liquid and gaseous fuels. The country has large quantities of agricultural and forest residues which can be used for this purpose. Indeed fuels from biomass may become the earliest alternative to petroleum for use in the transportation sector. Among the im-

portant questions concerning biomass however are the competing demands on land for different uses and the food-energy nexus.

6) *Hydrogen Energy:* Hydrogen is one of the most promising materials for use as a fuel as well as an energy carrier and storage medium. It can be used for transportation, electricity generation and for domestic and industrial applications. Serious efforts are being made in many countries on problems relating to production, storage and utilization of hydrogen. The present costs do not permit the use of hydrogen on a wide scale. However, if we succeed in generating hydrogen economically using solar energy, a whole range of uses will be thrown up and one can look forward to a 'Hydrogen Economy'. This is one of the exciting prospects for the twenty–first century.

7) *Wind Power:* There is tremendous potential of energy from the winds particularly in the coastal and hilly locations. In India in one stretch of Gujarat coast alone the potential is estimated to be 5,000 MW. Wind farms are already being set up in this coast and they will be operational within the next two to three months. One can foresee thousands of MW electric power would be generated from such farms as well as standard wind systems in the twenty–first century.

8) *Geo-thermal Energy:* The enormous heat potential at the centre of the earth can be tapped increasingly as developments proceed in economizing the technologies for tapping, drilling, piping and extraction of heat. A much bigger contribution from this source can be certainly expected in the twenty–first century.

9) *Energy from Oceans:* There is enormous potential of energy in the oceans which can be harnessed through the tidal system, wave conversion, ocean thermal energy conversion system and salinity gradient system. Tens of thousands of MW potential is available from the ocean thermal energy route around the Indian coast line itself. This is another interesting field for accelerating research and development to arrive at more and more economical designs to harness this potential.

Conclusions

The energy problem will continue to present a challenge to planners and decision makers. But it also presents opportunities for orienting the goals of economic and social development as also for continued scientific and technological efforts. A whole range of scientific disciplines have to be employed for effectively harnessing various sources of energy and for integrating them in a meaningful fashion. Downstream efforts in the form of pilot plants, product development, field trials and awareness promotion programmes have also to be organized and implemented. The energy sector has also been getting the highest allocation in recent five year plans. While this will have to be maintained, a clearer definition of priorities within the energy sector can help in a more balanced allocation of resources and lead to all-round development. If necessary steps are initiated right now and the momentum built up over the next fifteen years, non-conventional energy technologies alone can contribute to about 20 per cent of the total energy requirements of the country by the year 2000.

This will obviously require the fullest utilization of mature technologies for a great range of applications such as cooking, lighting, water pumping, stationery power, low and medium grade heat, and in future, transportation. The viability of these technologies should be judged not only in terms of pay-back period but also on the contribution they can make to preserving the environment and improving the quality of life in rural and urban areas. If these aspects receive the fullest consideration and adequate financial, material and manpower resources are devoted to them, the country can confidently enter the twenty-first century armed with a full range of energy technologies for its varied needs.

24

Fossil Fuels Use, Society and the Environment

R.K. Pachauri

Environmental Concerns

The basic approach of the Seventh Plan in respect of the environment and ecology is towards promoting sustainable development in harmony with the environment. The Plan document states that it would have to be ensured that all development programmes in all sectors will take environmental considerations fully into account.

The nexus between energy production, conversion and consumption on the one hand and environmental effects on the other is very strong. Throughout history, burning and other uses of fuel have produced undesirable environmental effects which have often caused difficult problems. In general, the developing countries in trying to promote economic development as rapidly as possible, have not done full justice to environmental protection, thereby going counter to the concept of sustainable development. It is only in the Sixth Five Year Plan that India, for instance, has recently made significant strides in articulating concerns pertaining to and measuring and evaluating effects on the environment caused by several developmental activities.

This period has also seen a tremendous growth in the involvement of individuals, action groups and institutions studying development in the context of environmental effects and changes. But the voicing of concerns and articulation of protests must not be mere rhetoric. The nature of science and its practice is such that there is no place in it for pompous statements and idealism divorced from analysis and rigorous measurement. The scientific community in this country which has not hesitated to express concerns and focus public attention on environmental degradation now needs to broaden its horizon to take into account specific actions which provide clear, implementable and constructive measures for designing and promoting a sustainable system for growth and economic welfare.

Indeed, nowhere is the need for quantification, measurement, and clear evaluation of costs and benefits more important than in the case of energy related environmental problems. For, nowhere is the effect of one sector more diverse and diffused than in the case of the energy sector on the environment. There are several forms in which the flows of energy in the economic system lead to environmental problems. The first of these is in the form of thermal pollution which can occur on account of direct heat loss to the atmosphere which in some parts of this country produce climatic effects detrimental to human comfort. There is the effect of energy use in the form of industrial cooling using bodies of water such as rivers and lakes. Very little analysis of this aspect is carried out, for instance, before the siting of a power plant. A typical nuclear plant generating 1000 MW of power can, for instance, dump up to 2000 MW of heat into the environment. A fossil fuel plant generating 1000 MW can dump up to 1200 MW of heat. To keep the temperature increase at 1°C, this fossil fuel plant would require 10,000 cu ft per second of water. The cumulative effects of power plants using large bodies of water have now reached a stage where this problem needs detailed and analytical investigation. The effects of temperature increases on aquatic life need to be evaluated for each specific location. Abatement schemes for thermal pollution may in some cases require to be built into the facilities for power generation themselves.

Air pollution from power plants is another problem which is assuming alarming proportions. The saying goes that 'the solution to pollution is dilution', and air pollution from thermal power plants is generally seen as an urban problem. But the impacts could be far more serious in non-urban areas, and yet these are always less visible and less noticeable. It is all very well to set up a pithead thermal power station in a remote area, but a concentration of large megawattage in a small location, even though at a distance from large urban settlements, could be extremely harmful for the natural resources and well-being of human beings over a surprisingly vast area. For instance, in the case of the Singrauli power station, D.R. Ahuja finds that even though, in general, Singrauli coal has only about 0.35 per cent sulphur, large-scale power generation can produce a cumulative effect from emission of sulphur oxides which could be quite serious. This has not been evaluated fully. Sulphur removing agents can be very expensive and could increase power plant costs by 25 per cent. In the case of retrofitted plants, they use up almost 5 per cent of the energy output of the plant itself. The typical method of reducing ground level sulphur concentration is to build very tall stacks to disperse oxides emitted over a large volume. This would be fine in a flat urban location where stacks can be made much higher than the tallest building, but in a natural hilly location with an undulating topography, the sulphur oxides could get easily trapped into a small area with high build up of SO_2 concentration.

The point of mentioning this example is that several organizations could, in the absence of a proper environmental impact assessment (going beyond mere words and platitudes), take actions which are detrimental to the environment and natural resources in a region. The Singrauli area has the potential of becoming a nightmare, in the absence of a lack of coordinated action and in-depth analysis prior to the implementation of proposed investment decisions. It is not enough to point out the dangers of pollution, but the effects of environmental damage need to be accurately assessed and quantified.

A Historical Perspective

One finds in reviewing the history of the environmental and ecological movement that the consciousness of societies to potential environmental damage has generally been raised as a result of large scale disasters that have taken place in the past. In 1948 as a result of extended inversion in the small town of Donora (Pennsylvania) in the USA 600 illnesses and 20 deaths were reported out of a total population of 14,000 in this small community. Perhaps the worst disaster was the London episode of 1952 in which between 3,000 and 4,000 deaths took place. The Bhopal disaster in our own country has been a grievously costly mistake in terms of human lives lost and serious health effects for the survivors. While this unfortunate disaster has raised the level of consciousness and debate on potential industrial accidents, was it really necessary for this costly mistake to have occurred? And even after it has occurred one does not know whether planners, decision makers and industrialists would keep the lessons of Bhopal in mind to avoid disasters in future.

Barry Commoner has recently analysed the reasons for environmental degradation. His contention is that a dramatic transformation in production technology has occurred in every industrialized country since World War II. Because the developing countries have pursued a similar path of industrialization, choices of technology in the Third World have been no different from those in the industrialized nations. In essence, according to Barry Commoner, rail freight has been displaced by truck freight in the transport sector of industrial nations, and in manufacturing, the amount of energy, especially in the form of electricity, used for producing goods and services has increased sharply. In consumer and retail products, re-usable goods have been replaced by disposable consumer items. All these have combined to intensify environmental degradation.

The rate of growth in demand for electricity in this country is at the same levels that were observed in developed countries in the sixties, when the real price of electricity was actually declining and demand was, therefore, growing at a rate such that it doubled almost every seven years. Power prices in this country are continuing on an upward trend but on account of the technological rigidities of consuming sectors like industry and the spread of household electricity use in urban areas, and energization of pumpsets in rural areas, demand continues to spiral upwards. In the case of the transport sector which is highly energy intensive, forecasts of growth made by various government bodies have been lower than the actual growth achieved. Two reports which dealt with this subject recently, namely, the Working Group on Energy Policy and the National Transport Policy Committee predicted transportation activity for 1982–83 which has been exceeded substantially as indicated in Table 1. Given this trend, our long term choices on modes and technologies for transportation need to be highly energy efficient.

TABLE 1

Traffic forecasts and actuals (for 1982/83)

(i) Railway	WGEP	NTPC	Estimated/Actual
Passenger traffic			
(Intracity) bpkms	44	50	45.8
(Intercity) bpkms	160	160	181.1
Freight traffic btkms	200	—	177.8
(ii) Road	**WGEP**	**NTPC**	**Actual**
Passenger (bpkms)	370	370	585
Passenger (bpkms)			
Car, 2-wheeler, taxi etc.	77.7	—	62
Passenger (bpkms) Bus	293.3	—	525
Freight (btkms)	114	—	148–179

Source: Advisory Board on Energy.

The production of energy from large central stations is a source of enormous pollution, as quoted above in the example of Singrauli. Again, according to Commoner, the present centralized technology of power production is a source of both thermodynamic inefficiency and adverse environmental impact. If this production was on a decentralized scale, then approximately two-thirds of the heat dumped into the atmosphere could be economically utilized through cogeneration processes. But since large power plants are generally at remote distances from populated areas, the cost of cogeneration and utilization of cogenerated energy make this technology prohibitive in several cases.

It is tempting to conclude that the problems of environmental degradation and higher intensities of energy use are a product of capitalist systems and free market economies. But this problem has serious dimensions in the centrally planned economies as well. While information is not readily available about the U.S.S.R., it is believed that large scale pollution from coal production and use are common, and minor nuclear mishaps have taken place in nuclear power plants in that country. In the case of the People's Republic of China, the series of hydro-electric projects on the Yangtse river has been stalled because it was realized belatedly that over 400,000 people would be displaced as a result of these hydro-electric projects. Our own analysis of the Silent Valley project and other large hydro sites points clearly to the serious ecological and environmental implications of large power projects.

What Should be Done

The inference that can be drawn from trends and developments in the past is that obviously there is a large gap between the appreciation of environmental science and economic planning. The two groups dealing with these areas are working in total isolation, and, therefore, very often at cross purposes. If a proper economic evaluation was to be made based on social considerations a number of viable projects included in the planning process would not be acceptable. On the other hand, environmental scientists seldom look at choices and measure the acceptability or otherwise of specific projects purely on absolute criteria, with little relation to costs and benefits both of environmental impacts and their abatement. A good example of this isolation between two groups is the choice of location of the Muradnagar thermal power plant being established by the National Thermal Power Corporation. After the location decision had been taken, an environmental impact assessment study was conceived of as an afterthought. The pressures on those conducting the study, who are funded by the organization responsible for setting up the power plant, would be such that serious doubts can be raised on the credibility and objectivity of such a study. This observation is not intended to be an indictment of the power planning mechanism and the electric power supply industry, but perhaps there is a deeper and more serious problem which relates to the establishment concerned with environmental science as well. The long gestation period and high capital costs of hydro-electric power plants has been one major reason for a relative shift in favour of coal based thermal stations. An obsession with environmental concerns to the exclusion of economic choices and trade-offs would only weigh against acceptance of hydro sites in the future. We may, therefore, have more thermal power plants providing very expensive peak power and causing much greater harm to the environment than alternative hydro power stations.

The pressure to rapidly develop supply of energy and the compulsions of rapid growth in demand arising out of our present pattern of development and growth will continue to be serious. These compulsions would lead to expedient solutions and disregard for environmental effects, which in the long run would prove extremely harmful and expensive to society. Given this fact and the enormous scarcity of capital being faced by the Indian economy, there is no choice but to follow an energy conserving path and essentially attempt to manage demand to bring down the rates of growth of the energy supply industry. Even if one looks at the aggregate energy/GDP ratio, the position of India is none too happy with the energy/GDP elasticity somewhere in excess of 1.5, and at the micro level there is no dearth of examples showing an almost total disregard for energy efficiency. This applies as much to agricultural pumpsets as to large industrial machinery and, of course, the entire transportation system. With growing incomes and rapid urbanization, similar concerns can be expressed for more modern appliances as well. Figure 1 shows the enormous improvements that have taken place in the efficiency of Japanese refrigerators. As against this the Indian record is very poor, and by international standards refrigerators, airconditioners, ceiling fans and even lighting devices in India are extremely inefficient.

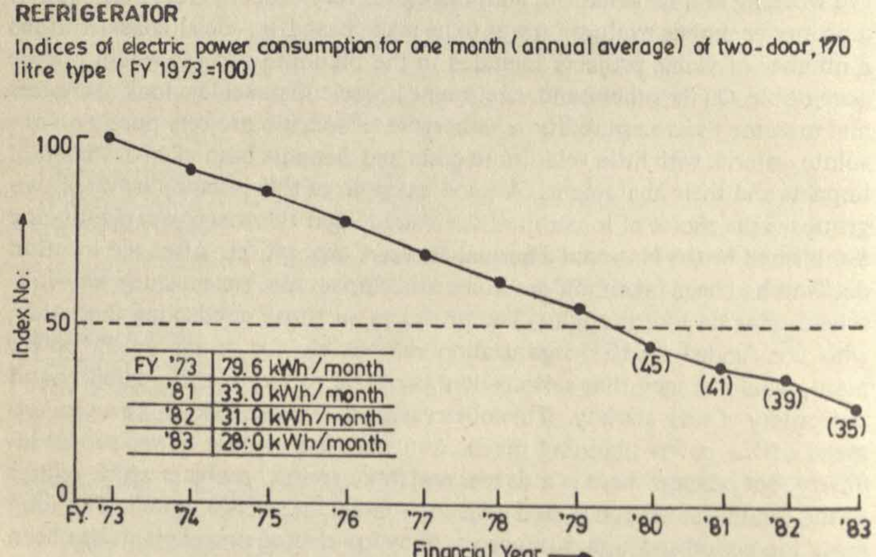


Fig. 1. A sample of electric appliance efficiency improvement in Japan.

The greatest potential for quick and early reduction of energy use intensities lies in the industrial sector. This is true as much of the large industries in the country as of the hundreds of thousands of decentralized units. The brick industry, for instance, which is essentially a small scale industry in this country consumes an estimated amount of energy in excess of 10 million tonnes coal replacement, of which at least 5 million tonnes can be saved through the implementation of simple technological improvements. The Inter-Ministerial Working Group on Energy Policy which carried out a comprehensive study of the potential for energy savings in the industrial sector found that even with simple short run measures which require very low levels of

TABLE 2

Potential energy saving in industrial sector

Conservation measures	Energy savings		
	Million tonnes coal equivalent	Rs. Crores	Investment Rs. Crores
Short-term			
House-keeping & insulation	7.8	700	400
Medium-term			
Waste heat recovery Instrumentation Control replacement with energy efficiency	9.4	840	1200
Long-term			
Process changes Computer Control Cogeneration	6.2	560	2000

Source: Inter-Ministerial Working Group on Utilization and Conservation of Energy, Summary volume, pp. 15–16.

TABLE 3

Energy intensities in selected industries

	Steel	Cement	Aluminium	Pulp & Paper	Ferti-lizer	Textiles
India	9.50	2.00	33.00	11.13	11.25	22.40
Italy	4.03	0.89	—	—	9.92	—
Japan	4.18	1.20	13.90	—	—	—
Sweden	5.02	1.40	16.50	7.56	—	—
UK	6.07	1.30	21.10	7.62	12.23	—
USA	6.06	0.95	9.50	9.70	11.32	12.10
West Germany	5.21	0.82	14.90	—	—	—
$\frac{\text{India-lowest}}{\text{India}}$ (%)	57.6	59.0	71.2	32.1	11.8	46.0
$\frac{\text{India-highest}}{\text{India}}$ (%)	36.1	30.0	36.1	12.8	−8.7	

Source: Indian figures are the author's estimates (1979–80) taken from the most reliable of recent sources.

Figures for other countries are taken primarily from Jankowski (1981) with the exception of Steel (National Productivity Council 1981 seminar) and Paper (National Productivity Council, 1983 Sectoral Report) investment, the returns in the form of energy savings were substantial. This is brought out in Table 2. The position of India with respect to the industrialized countries is brought out clearly in Table 3 which shows energy intensities in selected industries in several industrial nations and India. In actual fact even some developing countries such as the Republic of Korea have achieved substantially higher levels of energy efficiency than India. The positive feature of this very unfavourable comparison is that the potential for energy savings in Indian industry is very large, and if this opportunity is fully seized, the rate of growth in energy use could be brought down substantially in the Indian economy with modest investments.

In essence, these possible solutions make a great deal of sense, and yet not much is happening to implement them. It is, therefore, important to consider something in the nature of a national movement to which the leaders of Indian society and scientific thought must lend their fullest support. The theme of this movement should be to promote sustainable development by conserving energy wherever produced and wherever used.

25

Technology Adaptation for Community Development

M.M. Chakrabarty

Introduction

The census of 1981 indicates the population in our country to be 683.5 million and by this time it has probably exceeded 700 million. About 80 per cent of this population live in the rural areas. There are about 7 lakh villages in the country while number of urban centres is nearly 100. The yardstick for the poverty line is taken as Rs. 3,600 as the annual income. It is found that about 50 per cent of the rural population remain below the poverty line. Therefore it is estimated that the standard of living of about 280 million people is to be raised to bring them at par with the remaining rural population. Even if the question of poverty line at Rs. 3,600 in terms of a minimum standard of living (excluding the rates of inflation) is set aside, raising the status or eliminating the poverty of 280 million people is really a Himalayan task.

It is paradoxical, that when our country with a comparable manpower of technologists and scientists of high calibre is competing fairly well with the developed countries in such ventures like nuclear plan, space research, heavy industries, millions of our people have to dwell with their families in barely a room in environments which are not congenial to healthy living. Majority of the rural poor is engaged in farming which is again a seasonal activity though a little percentage of the population is engaged in rural industries, such as processing of food products, manufacturing of wooden products, garments, clothing, woolen products, paper, leather and other cottage industries. A portion of human resources in the rural areas consists also of illiterate landless labourers, marginal farmers, backward tribes, some semi-skilled village labourers such as potters, blacksmiths, carpenters, weavers and other craftsmen. There is a small percentage of educated yet unemployed mass, or literate but economically backward class of people. Very little has been done so far to help this large rural populace and utilise this human resource which are considered to be the wealth for any country.

Planning to Help

Let us examine the different efforts attempted by different agencies like the Government, and many other voluntary organisations. The Government of India started in the early fifties a 'Community Development Programme' involving various Departments of the Government. Projects under community development were undertaken in different blocks under the leadership of a project officer, and later 'National Extension Service' started functioning in the blocks consisting of many villages. The problems were: (i) very little money was allotted, and as a consequence it was difficult to divert money to many schemes on agriculture, veterinary science, health services, rural industry and education, etc., (ii) each Department used to prepare the Five-Year Plan budget independently and there was practically no coordination amongst themselves, and (iii) participation involvement of the people for which all these schemes were prepared was absent and whatever infrastructure and facility were created or provided, they have been used only by the privileged class of the society. So the expected results could not be obtained in spite of the noble wish and efforts on the part of the Government. Lack of input (money), coordination, above all people's participation are mainly responsible for the failure of the Community Development or NES programmes.

Then came the Panchayati Raj as per recommendation of the Mehta Committee which emphasised the need for formation of elected panchayats to implement the programmes for the poor villagers. Meanwhile, the concept of Community Development went on changing and Integrated Rural Development Programme (IRDP) was introduced during 1978–79. Later different schemes like National Rural Employment Programme, Rural Landless Employment Guarantee Programme and Training of Youth for Self-Employment Programme, were brought in. The National Rural Employment Programme which included both agriculture and village-based industry was quite ambitious. But the total allotment of plan-money and bank credit together was so meagre that no development in the positive direction was feasible for raising the standard of living of the rural population. Comparison of the total financial investment made in the heavy and medium industries in the public sectors with that made in the rural development reveals that there is a striking difference in the investment trend. The bank credit for rural people is very nominal compared to that allowed for the urban sector. It is true that heavy industries require a large investment, but the performance of the public sector industries is not so good and it is unfortunate that they can not generate sufficient employment or absorb the unemployed people. Bad management is the main root of the poor show of almost all the public sector industries. On the other hand private industries are dominated by rich urban people who are not in general concerned so much for lifting the status of the rural people. The entrepreneurship development is restricted to a small community among the rich and dominant group of families controlling the private industries of the country. It is apparent that there is no determined will and dedicated effort to look into the problems of the rural people, the vast majority of our population in spite of good wish towards the rural sectors.

Some efforts have been made by the Government of India on such programmes like Rural Industries Programme (RIP) and Rural Artisan Programme (RAP) to set up training institutes in rural areas.

There have been some successful programmes undertaken by the Government of India. One of the ventures is Agro Industries Corporation set up under the administration of the State Governments. These corporations have been mainly responsible for distributing the agricultural inputs like machinery implements and equipments for dairy, poultry, fishery and other allied agricultural industries.

A number of Programmes like Small Farmer's Development Agency (SFDA), the Command Area Development Authority (CADA) and so on have been operating in the country—all aimed at improving the conditions of the rural poor. They are all part of IRDP programme pursued till now. Similar services mainly in relation to the agriculture production are being provided by the Krishi Vijnan Kendra (KVK) sponsored by the Indian Council of Agricultural Research (ICAR). There is a plan for a Council for Advancement of Rural Technology (CART) on the same pattern of ICAR and that will coordinate the efforts of developing and discrimination of rural technology.

Boosting Morale—The Need of the Day

Given clear-cut objectives and necessary support, scientists, engineers, and technologists with the help of sociologists can solve the rural problems by adopting the right choice of technology for rural development. Engineering and technology can really change the present day scene of villages, convert them to modern villages closely matching with the people's aspiration. Engineering and technology can further unlock the creative potential of our people and can raise the awareness and infuse self-confidence among the villagers or the people living in the hinterlands of the urban centres.

Raising self-confidence is the most important task as the spirit of self-confidence can only build up an India of our dreams. The self-confidence induced through various forms like village reconstruction, development of cottage industries, promotion of the traditional skills, etc., were infused into masses of the rural block by great men like Rabindra Nath Tagore and Mahatma Gandhi. Poet Rabindranath Tagore established a centre at Sriniketan at Bolepur (West Bengal) to propagate the various skills and craftsmanship among the poor rural mass to let them lead a meaningful life. Mahatma Gandhi, infused self-confidence in his countrymen by his unique movement of *Charkha* and other concepts of village and cottage industries. His novel concept of *Nai taalim* again was remarkable at that period of time. In fact, Khadi and Village Industries Commission (KVIC) and Gramodyog are the concepts developed later on the innovative ideas of Mahatma Gandhi. KVIC has promoted not only *Khadi*, but also the processing of cereals, pulses, oil, poultry, leather, gun, *khandsari*, beekeeping, match stick, lac, lime, bamboo products, glue, tallow, and many other product processes relevant to the rural mass. However, the KVIC has accepted mechanized operation and use of electricity for enhanced production. But the investment in KVIC must be raised so that it can participate meaningfully to improve productivity.

The infusion of self-confidence was practiced by many thinkers and by men like Swami Vivekananda who first raised consciousness amongst the so-called educated Indian youth to serve the poor folk, Sri Aurobindo who established a centre in Pondicherry, and Sri Guru Saday Datta, the preceptor of *Bratachari* movement. What is really important is the generation of a spirit of work-motivation and developing skill for work maintaining harmony in the environment and the surrounding and inculcating a spirit of self-confidence and a commitment towards the social and economic upliftment of the country people.

Politics—Its Two Faces

A brief overview of the political scene is necessary as the country and its rural mass can only prosper if there is a political will. Since the first elections up to the most recent elections, it is seen that the political parties are growing in number. It may be that they all have a programme to eradicate the poverty of the rural people. In general, propaganda of political campaigns are based on slogans concerning rural development, but different political groups and parties have failed to implement their rural development programmes probably due to the fact that there is no firm political will or executive commitment for rural development. Whenever, there is violence, exploitation of the ignorance and poverty of the people, inter-party clashes on petty issues, inter-party frictions, inter-state, inter-caste quarelling and election violence, the poor suffer most. Sometimes such violence can put the freedom and independence of the country into danger. The political bosses must realise that the vast population is a wealth whose proper utilization under the right leadership only can pull up the standard of living of the rural masses so that they can, in return, contribute to build up the nation further.

Measures—Essential

Three important things that are essential for improving the lives of the vast rural population are: (a) political will to modernize villages, (b) application of science, technology and engineering for rural development, and (c) a well-knit planning from the bottom side of the structure to involve general mass instead of enforcing the same from the top.

In order to develop the infrastructure and extend the facilities for utilising the human resources in the best possible manner, the following areas are to be covered by adapting the right choice of technology: (a) Irrigation, (b) Agriculture, (c) Housing, (d) Sanitation, (e) Transportation, (f) Energy, and (g) Communication. Besides, the most important task will be to arrange education, training, and refreshing courses, which have to be of the continuing process.

Education and Training—The Prime Factor

Education and training are useful tools for any development process. Government should work together with the university people and voluntary organisations to make a complete survey of the needs of the villages, identify them and introduce the one step forward technology in an appropriate manner. The responsibility of orientation and training programme may even be left to the voluntary social organisations. Universities should be closely associated with the investigation of the field problems and devise solutions for them. A large number of the students just undergo higher education in colleges and universities without any exposure to the field problems of the villages. To this direction National Social Service (NSS) Scheme has been introduced in the University education system, but NSS schemes are suffering due to the lack of dedicated leadership. The students of general stream and professional branches should undergo a planned programme of training in field problems pertaining to villages in their course curriculum, as it is often found that the students are taught subject matters that have no direct bearing on the social upliftment of the people of the country. Universities with their existing facilities or if necessary with little capital expenditure are capable of designing such courses to adopt technology for rural industries and impart the necessary skill to the villagers.

Basic Needs and Infrastructures

BUILDING

Housing is one of the most basic constituents of leading useful and purposeful human life. More than 80 per cent of the houses are still made of mud. The Central Buildings Research Institute, Roorkee, has developed a good number of processes to build better rural houses. In villages, quality of rural building can be improved by adapting improved techniques as developep at CBRI like improved thatched roof, plastering with bitumen stabilized mud, fire retardant and water repellant paddy thatch. Waste water disposal system and suitable chimney for rural kitchen are some of the important items for which the minimum cost of construction and factor of durability can be assured by suitably adapted technology.

TRANSPORTATION FACILITY AND VILLAGE ROADS

Important market centres, rural health and family planning centre, cold storages, rice mills, etc. must be connected by the roadways so that villages can get the above infrastructural facilities according to their needs. According to 'Bombay Plan' of 1961–81, villages with population of 1000–1500 and within a distance of 1.5 km should be connected by metalled roads. It has been not possible still yet to make even fair weather roads all over the country due to the paucity of funds. Moreover, the planners have not yet recognised 'roads' as a core sector work. A comprehensive road development plan should therefore be prepared by the authorities like State Government departments, Gram Panchayats, Anchal Panchayats, Anchal Samities and other Command Area Development Authorities. Specification of rural roads, available road materials, cross-drainage structures, local road materials and maintenance of rural roads and village path are some of the important problem that can be tackled by suitable technology. The other important aspect connected to roads is transportation. Carts, bicycles, rickshaws, rickshaw-vans or taxis are the modes of transportation in the villages. Carts and rickshaws may be made of improved design. Volume of traffic is increasing. Hence, planning for not only of highways but also for village roads should be strengthened.

RURAL WATER SUPPLY AND SANITATION

Rural water supply and sanitation schemes require careful consideration right from the planning stage to the construction and subsequent operation, maintenance and repair activities. Supply of water to rural areas are done by small water supply systems that can be obtained from: (a) shallow tube wells, and (b) deep tube wells. Of course, big water supplies can be done from surface water supplies from rivers or lakes and infiltration galleries or from springs. Rural water supplies can be arranged from hand tube wells, deep tube wells or ring wells. However, the major problem with all these wells or pumps is the maintenance schedule. So training is necessary about the methodology of operation, maintenance and repair of all the essential components of the water supply systems.

Similarly low cost, technically feasible, environmentally sound easily maintainable and society wise acceptable sanitation arrangements must be made for the rural population. Here community participation at local level is most important.

RURAL INDUSTRIALISATION

The per-capita distribution of cultivable land is negligibly small in India and specially in the eastern and north-western region due to the influx of refugees. Apart from the regional imbalance, a large number of people from the rural areas from within the State as well as adjacent States move towards the city of large urban centres where there are agglomeration of heavy and medium scale industries both in the public and private sectors. Not only that, the intelligentsia are also coming to live in the urban centres leaving their ancestral village homes. As a consequence, our villages where greater population live are becoming backward and inequalities in wealth and income are growing to such an extent that rural people are getting frustrated and they are not getting the desired social justice. Therefore, for the upliftment of the essential social and economic needs of the rural areas, it is imperative to convert the backward rural areas into modern villages that people aspire for. Who amongst the villagers do not like to possess a radio, stereo or television? Who among the villagers do not like to have a cinema, good transport, healthy living or good schooling or vocational or industrial training facilities? The stagnant villages must be transformed into productive economic community.

In order to do that, rural industrialisation should be adopted on war-footing. Since economic viability is an important criteria, traditional type of industries using traditional skills and technology must be discarded or replaced immediately. In rural areas mainly two types of industrial activities can be developed:

a) activities based on local raw materials, and

b) activities based on local demand.

The industrial activity including cottage industries may centre round processing of agricultural produce, canning of fruits and vegetables, mineral products and diary products, poultry, leather or forest produce.

Activities based on local demand may be round the setting up of agricultural implements, sheet metal works, in repair and service workshop for cycle parts, hand pump, hand tools, printing, bell metal work, carpentry, furniture, building materials paints, varnishes, blacksmith and so on. In the latter activities, adequate infrastructural facilities with electrical power, communication, transport and enterprise need to be supplied. Mechanization to small degrees is necessary to make them economically viable, even if they are mostly labour intensive. Another important aspect is the marketing facility for the products produced by the artisans. The sales promotion can be enhanced by frequent exhibition held in different rural or urban interface areas; planning of the industrial cell, equipment, raw material, credit facility, quality control, etc. should be taken care of by the administration and cooperative authorities.

Government of India with the help of State Governments have taken steps for setting up District Industries Centres to provide services and facilities to small scale and cottage industries. In the rural-urban interface areas, of course, small-scale and ancillary industries should be set up.

TRAINING FOR RURAL INDUSTRIALISATION

To make the rural industrialisation meaningful and worthwhile, imparting training is very important. There have been debates amongst the scholars about what should be the type of training needed. There have been some patterns of training pursued in different State-owned industrial institutes, privately organised training institutes or institute run by many voluntary organizations. But the type of training should be such that a productive skill linked with environmental opportunities must be acquired by the trainee from the productive experience that will be illustrated by different models of the course curricula. Another important aspect is the infusion of self-confidence or development of altitude towards a specific productive skill.

A traditionally educated person is usually trained in a narrow domain of vocational skill and as a result, he can not employ his skill which is limited in its scope and content to a rural environmental setting as that particular specialization may not be demanded in his area where he lives. Naturally, he suffers because of his lack of mobility and flexibility in production skill. On the other hand, a guided training programme can be imparted to groups of trainees who can be trained not only in one single productive skill, but to several vocational skills. In each group, a suitable trade mix can be determined depending on the background of the entraints. Depending on the nature of the trade mix courses, training duration can be determined. However, compulsory training should be made mandatory about:

i) Preparation of Projects,
ii) Book keeping and Accounts,
iii) Costing, and
iv) Marketing.

This really would uphold not only the spirit of dignity of labour, but also provide them a feel of work experience. This is what, probably, the people in the rural areas need. Such an experiment has been conducted by the K.D. Mullick Institute located at Dakshin Jagaddal, West Bengal where courses with suitable trade mix are being run for young men and women taken from rural areas. A blending of duty and joy through 'Bratachari' synthesis has been introduced into their training structure and this, I believe, inculcates a spirit of belonging, integration, and environmental harmony along with the acquisition of productive skill. In the K.D. Mullick Institute, after the courses are over, the trainees are encouraged to set up individual or cooperative ventures. Self-employment and entrepreneur development are also encouraged and assisted by special cell created for this purpose.

Agricultural Sector

In India most important agricultural community in rural sector is perhaps rice. Its processing, storage, transport and marketing provide jobs to more labours than any other industry in the country. The monetary value of rice is the largest among agricultural commodities of the order of 500 crores of rupees for a production of about 70 million tonnes of paddy. There are more than 83,000 mill units in the country which deserve immediate attention and thorough improvement. Of course mills 73,000 are under productive metallic hullers and only 10,000 are in organized sectors consisting of: (a) battery of hullers, (b) sheller-cum-hullers, (c) shellers, and (d) modern mill of varying capacities and efficiencies. The hullers are inefficient machines not only in terms of milling out-turn but also in relation to the by-products. Hullers yield about 5 per cent less rice and produce a mixture of husk and bran which cannot be used for extraction of rice bran oil. Moreover, the bran is a poor animal feed and the husk is also not fully recoverable. Government of India is aware of the problem and hence introduced amendment of the Rice Milling Industry (Regulation and Licensing) Act in 1958 and rules thereof in 1970 introducing conditions as to improvements in existing machinery, replacement of machinery and use of improved method of rice milling as may be necessary to eliminate waste to obtain maximum production and improve quality of milled rice. The amended Act and Rules thereof provide provision for progressive replacement of battery of hullers, huller-cum-sheller combinations by modern equipment like paddy cleaners, rubber roller shellers, paddy separators and improved whitners. Unfortunately, the progress has been extremely slow. Although mini modern rice mills of capacities ranging from 250–500 kg/hr are available in the country the huller mill owners have not been persuaded to accept it perhaps because of lack of enough R and D efforts and promotional efforts on the part of the Government to create confidence in small entrepreneurs. Since bran is the most important by-product of rice milling industry, mini modern mills will be economically superior to hullers only if the value of better bran is considered. The mini mills can sell the rich bran quickly to central solvent extraction plants located in many places throughout the country. The rice bran has an inherent problem of deterioration through the activity of lipolytic enzyme which increases the FFA considerably making the extracted oil unsuitable for edible purpose. Hence stabilization of the bran is required after milling in case the extraction of oil is delayed. The mini mills can set up stabilizer unit also along with the mill which will ultimately improve the industrial activity in the rural areas. At present the rice bran potential in the country is of the order of 2.4 million tonnes, from which 0.4 million tonnes of rice oil valued at Rs. 400 crores and 2 million tonnes of deoiled bran would be produced. It is a matter of regret that in 1980–81 only 0.9 million tonne of rice bran were extracted and only 0.13 million tonne of rice oil was produced. But not even 5 per cent edible grade rice oil was produced from the extracted oil whereas Japan produces only the fifth of the rice produced in India yet it manufactured about 0.12 million tonne of edible grade rice oil.

It is necessary now that we should place adequate emphasis on increasing our fixed oil production keeping in view that it is not only a source of food but also a renewable source of energy for the future. Our country imports today 2 million tonnes of edible oil valued at Rs. 1000 crores which is next to our mineral oil import bill. So all efforts should be made to produce oil from all possible kinds of sources. In present day energy crisis, vegetable oil could also be a substitute for diesel as such or by simple conversion processes. Hence every effort should be made to increase our vegetable oil production.

There are many other by-products from rice milling industry which could be of enormous commercial value. Rice husk, rice husk ash, husk board, rice bran wax, etc. are some of the products which require R and D support to establish their commercial value.

Another important agricultural material which could generate economic activities in rural sector is perishable seasonal foods like fruits and vegetables. Cottage scale food preservation units could be built up to preserve the seasonal surplus to cater to the needs of both urban and rural market. Food is a commodity whose demand is likely to remain steady for many years in India. But the processed food has to be low cost and should be within the purchasing power of majority of the people. Simple methods of preservation retaining high food value in the product should be encouraged. Many vegetables like carrot, cabbage, cauliflower, green papaya, reddish peas, beans, etc. can be well preserved for a few months by fermentation with only addition of small amount of salt practically at no cost. The product is well known in other countries and should also be acceptable to our people. Dehydration of fruits and vegetables is already being practiced on commercial scales in rural sector, particularly for materials like peas, potato, mango, green banana etc. But these sundried products are of inferior quality. So proper scientific input is required for expanding this industry and opening up new areas by introducing better economics and newer products.

Fishery

Another noteworthy perishable food is fish which could be an important raw material for agro based industries in rural areas particularly in the coastal zone. World fish production has been around 75 million tonnes in recent years as compared with about 120 million tonnes of all kinds of meat (beef 40 per cent, pork 35 per cent, poultry 20 per cent, sheep/goat 5 per cent). This quantum of fish is certainly low when compared with the production of grains. But its nutritional importance cannot be ignored. Fisheries contribute about 6 per cent world's supply of protein and about 18 per cent of animal protein. Approximately 20 million tonnes of fish are reduced to fish meal which contribute only indirectly to human nutrition. The world average annual per capita consumption of fish is about 13 kg compared to 28 kg for all meat. Fish is equivalent nutritionally to meat in protein but at the same time it high in unsaturated fat and high in essential minerals. At least 75 million people in the pacific basins, South-East Asia, Indian Sub-continent and coastal Africa and South America derive 50–80 per cent of their animal protein from fish harvested from coastal zones, estuaries and fish ponds. We have to keep in mind that almost all species used for fish meal production can be processed into palatable food.

India has a long coast line of about 4607 km and continental shelf of 259,000 sq km. But the total marine fish catch is hardly 2 million tonnes. There is scope for not only increasing the fish catch in the country but also large part of the fish which is improperly used through fish meal can be processed into edible and acceptable forms of fish products. Export of frozen marine products started in India only in 1953. It has now become an organized sector of industry exporting products worth nearly 250 crores of rupees. The products include frozen shrimp, canned shrimp/frozen froglegs, frozen lobster tails, dried fish, dried prawns, shark fins and fish maws. Though the export market is steadily rising, large part of fish so called trash fish are very inefficiently and improperly utilized. One of the simple and low cost method of preservation of fish is drying. It should be realized that sundrying alone will not provide always the desired rate of drying and produce a product having desirable moisture content at all place in the coastal zone. Hence in order to produce an acceptable and safe quality of dried fish it is essential that improved technologies of processing and drying are adopted.

Improved solar driers or flue heated tray driers or electrically heated tray or fluid bed driers could be of immense value in meaningful utilization of fish, which are highly perishable in nature. It is a pity that even today in many parts of the world, where fish trawlers operate in the sea a large portion of the catch is thrown away into the sea. In the Carribbean Atlantic it has been estimated that for each 1 kg of shrimp caught 51 kg of fish are discarded. The fish from the by-catch can be dried in pieces or dried in the form of fish protein concentrate (FPC), type C as specified by FAO. The fish can also be made into salted, smoked and pickled products, as well as into, minced fish, fish sausages and fish pastes having extensive market demand. Hundreds of small scale factories could be built up in the coastal area of the country to do such job which would not only benefit the fishermen but also the rural people connected with fishing and allied skills.

Energy Scene

Utilization of solar energy has received high priority for obvious reasons. While photovoltage cells are drawing active attention at the research level, simple methods of utilization of solar energy in solar cookers and solar driers appear to be feasible in villages. People are trying to develop and use solar cookers in order to reduce consumption of cooking fuels. In many countries scientists are working to advance the state of art. But so far till today practically no one in the developing world is using solar cooker on a regular non-subsidised basis. One of the reasons for such failure is that a relatively high temperature is required to cook food. But for food drying the temperature requirement is much lower. So solar dehydration of food could be a more feasible proposition. Simple flat plate collectors are good enough to raise the temperature to the desired level. Constructions of Solar driers production of novel items of dehydrated foods marketing and promotion of the products can generate brisk economic activity resulting in creation of large employment potential as well as improvement in the nutritional status of the rural people.

In certain areas wind could be an important source of power generation in rural area and can be used without much efforts in cases which can tolerate uneven power output such as pumping of water from well or generation of small quantity of electricity. Although capital investment is high but in the long run wind mill is economic compared to conventional energy set ups.

Biogas could be another important source of power for the villagers. In the rural sector it is estimated that 45 per cent of domestic fuel requirement come from burning dung and 55 per cent coming from firewood. About 1.2 billion tonnes of wet cowdung is available in India, which is equivalent to 30 million gallons of petrol. It is well known that when dung is converted into biogas and manure the fuel value and manure value are more when compared with the dung used directly for burning of compositing into manure.

Research in Biogas technology should be taken up with right earnestness as biogas can generate enormous economic activity in the rural area. It may be appropriate to install community biogas plants in suitable locations in order to obtain maximum gain from such installations. It is encouraging that the country's first community biogas plant was set up by the Planning Research Action Division (PRAD) of the State Planning Institute of Uttar Pradesh at Fateh Singhka-purwa in Etawah District in UP with financial assistance providing by UNICEF. The Plant which became operational in March 1979 has attracted considerable attention within and outside the country. The Seventh Five Year Plan has placed special emphasis on Community Biogas Plants for which adequate steps are being taken. We should bear in mind that in order to make technology acceptable and economical for rural application R and D has to be an important component of planned development. If the cost can be further brought down the biogas technology could be one of the important input for all round development activity in villages.

Conclusion

The problem of poverty in the rural sectors is so enormous that a strong political will, and a national effort on war footing will be required to tackle the issue. The major thrust should be technology adaptation in villages or cluster of villages. The right choice of technology and new outlook of productive technique for the activities based on local needs and local raw materials are very important tasks to be accomplished quickly. The in-service training, education, refresher courses and the work experience during the training are very important. The University and college students should be involved in the field work during their course of studies so as to identify the areas where innovative production techniques for improved productivity can be adopted. The Universities can also set up rural industrial parks in the villages where technology transfer can be demonstrated or exhibited to popularize and raise awareness amongst the villagers. Simplified management training, entrepreneurship development, arranging bank credit and above all infusion of self-confidence, developing leadership are some of the important elements of social engineering that must be propagated. The planning for any rural development should start from the bottom of social structure and should not be enforced from the top as is the usual practice. The involvement and participation of the rural people to convert their neglected ancestral villages to modern villages with the aid of up-to-date relevant technology can stimulate the entire process and solve the challenging task of eradicating poverty, the greatest curse of the society.

26

Industrial Environment in India

S.S. Ramaswamy

Introduction

Any discussion on 'industrial environment' should normally cover many aspects such as pattern of industrial development, prevailing industrial relations, level of productivity, safety, health and welfare of workers, pollution control etc. Whereas all these are important, the areas of interest to a gathering of scientists, are the technical aspects of safety, health and pollution control; which alone are covered in this lecture.

Even though rapid industrialization has been on in the country during the last three decades or so, only of late is great concern being shown over the safety, health and environmental hazards posed by the developmental activities in many economic sectors such as manufacturing industries, mining and agriculture. In a review of the present state of the industrial environment in the country, it is essential to consider the pattern of industrial development which has taken place in the country in the recent past, the problems created by such development, and the potentialities to be faced in the future. Such a review has also to cover, among others, the physical and psychological aspects of the working environments which have an impact on the workers. Analysis of the infrastructural facilities that have been built up to tackle the problems created by industrial activities, the inadequacies inherent in these, and the remedial measures to be adopted in future, is also to be included.

Growing Population—The Biggest Problem

The country's foremost problem has been, and continues to be the population explosion. When we became a sovereign republic in 1950, already the population was a staggering 361 million. With the then prevailing near total agricultural economy, that too with low productivity (the production of total food grains was only 0.52 tonnes per ha in 1950–51 as against 1.03 tonnes per ha in 1981-82), and the associated low level of national income, even the basic requirements of the entire population such as food, clothing, housing, transport and other daily necessities could be met only minimally. Even this threatened to be eroded by the unchecked and continued growth in the population.

Industrial Growth in the Last Three Decades

Thoughtfully, the policy makers realized that with the alarming rate of continuing growth in population (nearly 2.5 per cent per annum) only through quickly executed developmental projects could the basic requirements of the people be maintained at least at the low levels, if not hiked to levels comparable to those in the developed countries. These developmental projects covered naturally all the important sectors like irrigation, power, mining, manufacturing and construction. There was a phenomenal growth in output in all these sectors, and in particular, the performance in the mining and manufacturing sectors, was striking. For instance, in the three decades after attainment of independence, the growth was four fold in coal, over 80 fold in crude petroleum, 14 fold in iron ore, eight fold in steel, 53 fold in aluminium, 245 fold in fertilizers, eight fold in cement, 48 fold in caustic soda, 155 fold in refinery products, five fold in wagons and nine fold in automobiles (Table 1). Similar was the trend in construction activity also (Table 2). While these were welcome achievements which improved the standard of living, they had also their adverse side effects.

Occupational Hazards

Such spurts in industrial activities led to the use of more and more sophisticated machinery and equipment which has created the problem of matching between these and the physical and mental capabilities of the men handling these. The outcome of this has been the risk of bodily injuries to the operators. Many toxic and hazardous chemicals and other substances such as benzene, mercury, lead, vinyl chloride, organo phosphorus compounds, asbestos etc. which could give rise to typical occupational diseases, are also being handled in increasing quantities. High levels of noise and vibration, exposure to which will lead to loss of hearing and nervous debility, are also present in modern industrial operations (Table 3).

Safety Statutes—Impediments in Enforcement

The Government of India was aware of these potential hazards at work places and realized long ago that these could be eliminated or at least minimized only through rigorous implementation of control measures. It was further realized that such control at source would not be forthcoming unless

TABLE 1

Growth in production during the last three decades, in some of the industries in different sectors of economic activities, along with projections for 2001 A.D. in a few cases

Sector/industry	Units	Production during		
		1950–51	1982–83	2001 A.D.
I. *Mining:*				
Coal including lignite	million tonnes	32.8	136.9	1070
Petroleum crude	"	0.25	21.1	
Iron ore	"	3.0	32.5	
II. *Metallurgical:*				
Steel ingots	"	1.47	11.03	
Aluminium	'000 tonnes	4	211.5	5400
III. *Manufacturing:*				
a) *Mechanical engineering*				
Rly. wagons	'000 tonnes	2.9	15.4	
Automobiles	"	16.5	151.4	
Motorcycles and scooters	"	NA	399.8	
b) *Chemicals and allied:*				
Nitrogenous fertilizers	'000 tonnes of N	9	3424	60800
Phosphatic fertilizers	'000 tonnes of P_2O_5	9	980	
Caustic soda	'000 tonnes	12	577	7800
Cement	million tonnes	2.73	23.3	183
Petroleum refinery products	"	0.2	31.1	196
c) *Textiles:*				
Cotton yarn	million kg	534	1218	
Cotton cloth	million metres	4215	7953	
d) *Food:*				
Sugar	million tonnes	1.13	8.23	
IV. *Plantations*				
Tea	'000 tonnes	277	567	
Coffee	"	21	135.9	
V. *Power*				
Electricity	billion KWh	5.3	130.2	

the managements were made aware of what should be done, and were subjected to statutory compulsions to do so. This led to legislation of appropriate safety and health statutes, and their periodical updating through suitable amendments. The Mines Act of 1952 as amended in 1983, and the Factories Act of 1948 as amended in 1976 are two major safety statutes which in 1981

TABLE 2

Some of the additional 'construction' activities in the country completed during the last three decades

Nature of construction work	Quantum of work completed
Surfaced roads	567,000 km
Unsurfaced roads	569,000 km
Rail track	16,649 km
Major and medium irrigation projects (dams and canals)	1,127 km
Factory premises	110,483 km
Residential flats/houses (mostly more than single storeyed in urban areas)	1.5 million
Houses in rural areas	2.19 million
Telephone connections	2.813 million
Buildings for	105 Universities 7216 Colleges 419300 Schools 180 National laboratories 76 Medical Colleges New hospitals with 364,000 beds

TABLE 3

Prevailing noise levels in some typical industrial operations/locations

Industry/location	Sound pressure level (dB_A)
I. *Pharmaceutical Units*	
i) Fermentation (primary filter area)	114–128
ii) Air compressor	97–110
iii) Biological treatment plant	94–103
iv) Diesal generator house	98–118
II. *Foundry in Motor Manufacturing Plant*	
i) Moulding machine	114–120
ii) Pneumatic chipping/grinding	104–108
III. *Heavy Engineering Industry*	
i) Hammering of steel (15 metres away)	94–95
ii) Grinding inside cylindrical vessels	105–112
iii) Air escaping from grinder	124
IV. *Synthetic Fibre Manufacturing Plant*	
i) Polymer ribbon cutting	105–117.5
ii) Staple spinning laboratory	90–95.5
iii) Weaving laboratory	90–99
V. *Cotton Textile Mills*	
i) Weaving department	99–105
ii) Shuttle loom shed	92-96

(Data from Central Labour Institute)

covered nearly 7.17 and 0.75 million workers respectively. With the current annual growth rate of about 4 per cent in the employment in factories, by the year 2001 the workforce in the estimated 350,000 registered factories alone can be expected to rise to nearly 13 million! It is to be borne in mind that these registered factories are only those which employ ten or more workers and make use of power, and those which employ 20 or more workers and do not make use of power. There are numerous other still smaller units which are not covered by the Safety Statute. Even among the registered factories, nearly two-thirds are small units employing less than 20 workers. Thus it is the problem of magnitude and scattering which also comes in the way of enforcing safety measures in such scattered small units, whose priorities are different.

If one analyses the potentialities, one has to accept that the number of units handling chemicals are bound to have a phenomenal growth. While workers in such units may have to inhale a host of chemicals and, in a few cases, absorb them also through the skin, they have also to suffer from synergistic effects. Simultaneous exposure to high temperatures, deficiency in nutritional level, and high degree of physical exertion are all added stress factors which aggravate the toxic effects on the concerned workers. Poor personal hygiene habits among workers make things worse.

Statutory Safeguards

The redeeming feature is that the statutes contain adequate safeguards. The Factories Act contains well drawn out provisions to prevent injuries due to accidents, and health impairment due to inhalation of toxic dust, gases and fumes at work places. Reporting of accidents and of 22 'notifiable' occupational diseases is a statutory obligation. Pre-employment and periodical medical examination of workers engaged in a number of hazardous processes (like lead, manganese, chromium, asbestos, pesticides, carcinogenic chemicals etc.) is also a measure with which ensure health protection. Unfortunately, compliance with these provisions leaves much to be desired. Only accident reporting has been satisfactory, and could provide a tool to evaluate the effectiveness of our accident prevention programmes, and plan further activities. Similar is the experience with Mines Act also.

Achievements in Controlling Accidents

Considering the trend of physical injuries as revealed by such statistics, we have reasons to be happy over our achievements in the past, both in the factories and in the mines (Table 4). The rate of non-fatal injuries per thousand workers which was 53.0 in 1978 came down to 46.4 in 1982. In particular, achievements in the chemical industry were spectacular. The rate which was already as low as 29.2 per thousand workers in 1978 came down to 24.1 in 1980. In the mines the rate of 'serious injuries' could be maintained

TABLE 4

Incidence rate of reportable injuries per thousand workers in some industries

Major industrial group	Incidence rate in 1976	1978	1980
All industries	49.0 (0.14)	50.8 (0.12)	45.2 (0.09)
All textiles	102.1 (0.08)	116.2 (0.09)	103.7 (0.05)
Chemicals and chemical products	30.1 (0.23)	29.2 (0.19)	24.1 (0.24)
Basic metals and alloys	48.5 (0.26)	58.3 (0.28)	35.9 (0.17)
Machinery, machine tools and parts except electrical machinery	45.2 (0.11)	46.4 (0.10)	36.4 (0.07)
Transport equipment and parts	53.0 (0.13)	52.7 (0.06)	46.4 (0.05)

(Figures in parentheses denote fatal injuries)
(Source of basic data: Labour Bureau, Simla.)

at the low level of around four per thousand. We cannot, however, be complacent, since the rate of fatal injuries did not record any such fall. Another point to be kept in view is the severity of the accidents in the chemical units. Some of these can be very disastrous, as was the case in Bhopal.

Poor Documentation of Occupational Health Statistics

Unfortunately, we do not have such detailed information on the occupational health status of workers. Even though research studies have revealed the possibility of considerable prevalence of occupational diseases, the figures officially reported are very meagre (Tables 5, 5a, 6). We do not have compilation of the findings of the periodical medical examinations carried out on workers in dangerous processes. One may even be led to think that perhaps, our working environments are pollution free and safe which is not the case.

Storage of Technical Manpower and Equipments

A major contributing factor for such a state of affairs, is the inadequacy of technical manpower for carrying out even statutory inspections and investigations. For instance, through one of the amendments to the Factories Act in 1976, all factories employing 1000 or more workers, and even some of the smaller factories engaged in hazardous processes were made to appoint qualified safety officers to help the managements in their safety activities. In early 1984, it was reported that there were only 300 safety officers in the entire country against the requirement of 1500! However, the four Labour

TABLE 5

Potential diseases/ailments arising from typical industrial pollutants

Industry	Major pollutant emitted	Typical diseases/ ailments	Incidence recorded in India (%)
Mining			
1. Coal mining	Coal dust with mineral content	Pneumoconiosis	15.2
Manufacturing			
2. Asbestos cement	Asbestos fibre	Asbestosis	7.0
3. Caustic soda	Mercury vapour	Mercury intoxication	25.0
4. Cement	Dust of limestone clinker and gypsum, coal and cement	Chest pain	32
		Epigastric pain and stomach disorders,	7
		dermatitis	7
5. Dichromate manufacture	Dust and fumes containing hexavalent chromium	Nasal cartilage perforation	20.9
		Ulceration of the nasal septal mucosa	20.6
6. Cotton textiles	Cotton dust	Byssinosis	11.3
7. Ferrous forging	Noise	Noise induced hearing loss to different degrees	61.5
8. Lead acid storage battery units	Lead fumes and dust	Lead poisoning	9.1
9. Pesticide formulation	Parathion	Sweating	74
		Headache	65
		Giddiness	44
		Blurring of vision	26
10. Potteries and ceramics	Silica dust	Silicosis	16
11. Refractories	Silica dust	Silicosis	21
12. Slate pencil workers	Silica dust	Silicosis	54.7
		Conglomerate silicosis	17.7
13. Solvent extraction	Benzene	Dermatitis	54
		Fatigue and gastro-intestinal disturbances	50
		Nose and gum bleeding	26
		Lowered RBC	10
14. Textile dyeing	Nitrogen oxides, chlorine, etc.	Lowered pulmonary functions	7
15. Viscose rayon	Carbon disulphide	Exaggerated reflexes	62
		Sleep disturbance	29
		ECG abnormalities	6.2
Agriculture			
16. DDT spraying on crops	DDT	Slight changes in neurological responses	20
17. Plantation work (field work)	Organophosphorus, pesticides	Lowered cholinesterase activity	—

Note: All the pollutants from manufacturing units are also emitted into the general environment surrounding the units, as fugitive emissions, and may affect the general population in the long run.

Source of data:

1. Directorate General, Factory Advice Service and Labour Institutes, Bombay.
2. National Institute of Occupational Health, Ahmedabad.

TABLE 5a

Impact of age and duration (years) of exposure on the hearing level of workers in a forging unit

(Exposure noise levels ranged from 86 to 110 dB_A)

Age group (years)	Exposure (Years) 0–5	6–10	11–15	16–20
		Mean hearing level in dB		
21–25	20.0	28.5	—	—
26–30	25.0	33.1	58.3	—
31–35	22.5	47.4	57.5	—
36–40	—	47.7	59.7	—
41–45	—	—	40.0	—
46–50	—	—	—	52.5

Note : Higher bearing level denotes greater degree of hearing loss.
(Data from Central Labour Institute, Bombay.)

TABLE 6

Occupational disease cases actually reported from factories (1980) and mines (1983)

Sector	Occupational disease	Number of cases
Factories	Asbestosis	1
	Benzene poisoning	2
	Chrome ulceration	2
	Contact dermatitis	2
	Halogen poisoning	7
	Silicosis	15
	Toxic anaemia	3
Mines		
(Coal)	Pneumoconiosis	72
(Copper)	Silicosis/Pneumoconiosis	14

Source: Indian Labour Year Book 1982 & D.G.M.S.

Institutes under Directorate General Factory Advice Service and Labour Institutes, Bombay, and a few other agencies are conducting regular diploma courses and train such safety officers in large numbers. This will gradually wipe out the deficiency.

The situation concerning occupational health set up is worse. The number of certifying surgeons who are to carry out the statutory pre-employment and periodical medical examinations of workers in specified hazardous processes, was only 15 and the number of medical inspectors only 29 in 1984 in the entire country. Still worse, there is no readily available statistics on the number of full-time and part-time plant medical officers in position. If one considers the special monitoring and diagnostic equipments available in the country, the situation is no better.

Casual Approach in Complying with Statutory Provisions

A startling fact which was brought out by the Bhopal tragedy and the subsequent inspections of hazardous units in some parts of the country, was that there has been a casual and ritualistic approach in complying with even the important provisions of the Factories Act. An essential requirement for issuing licence for a factory, and for annual renewal of licence, is that detailed information on the manufacturing process is to be provided by the management. This should, naturally, mean details about the nature and quantity of the raw materials used, their toxic nature, the nature of finished products etc. Such information would enable the inspecting/approving agency to identify the specific safety requirements, and check whether these have been complied with or not, even before the manufacturing process is started. Unfortunately, till now, only sketchy information seems to have been provided in such applications. Only after the recent happenings, frantic efforts are being made by all the states to gather such information in detail, particularly in chemical units. Similarly, there are other provisions about the periodical testing of pressure vessels, pipe lines etc., which appear not to be carried out systematically.

As regards pollutant emissions through effluents, there are suitable provisions in the Factories Act as well as in the Acts to control Air and Water Pollution. But, if one considers the facilities in the country for monitoring the pollutants, it is a sad story. Even in the few surveys which are conducted to monitor the pollutants in the effluents from factories, there is a conservative 'beaten track' approach exhibited. The parameters studied are the relatively less toxic gases of SO_2, NO_x, SO_3 etc. More toxic and some times lethal gases which escape from special processes are not monitored.

Improper Location of Hazardous Units

In industrial pockets where hazardous units are operating, a major factor contributing to the pollution threat to the general population, is the location of the units. In our race to industrialize the country, influenced by many considerations such as easy availability of inputs like water, power etc., the socio-economic conditions prevailing in the areas etc., units have been set up without much consideration for the meteorological factors and environmental impact. Besides, when most of these units were initially permitted to be set up, they were practically in isolated areas far from habitation. Later on, when pressure for residential areas built up, due to lack of coordination, the local administration authorities seem to have permitted construction of houses close to these units. Slums have also sprung up around these units, mostly because of the desire of people to stay close to their work places. After a certain lapse of time, when pollution threat is faced, tremendous administrative problems arise in shifting either the units or the residences. Recently, some of the hazardous units situated in vulnerable areas in Greater Bombay have been asked to shift to far away places. Whereas, from pollution control, this is a must, it may give rise to problem of housing for the workers in the new areas, and of transportation. Besides, there is the problem of transportation of hazardous chemicals from these distant places, and the possibility of leakage and spillage on the way, which warrants systematic training to be imparted to the drivers of the chemical tankers to handle emergencies.

Attitude Deficiencies

Added to the above organizational deficiencies, there is also the deficiency in the attitude of the concerned people. There seems to be a lack of appreciation of the importance of safety measures. Many of the industrial accidents seem to result from human error arising from negligence. When the causes of accidents in a variety of industries, were analysed a few years ago, it came out that a large percentage of accidents was due to simple and easily avoidable causes like poor house-keeping and poor maintenance of machinery, unguarded machinery, non-use of personal protective equipment and adoption of unsafe material handling practices. Similar simple causes were also responsible for toxic exposures in chemical units (Tables 7 and 8). This means that the personnel concerned are not made aware of the necessity to observe safety principles scrupulously. Some of the queries raised (after the Bhopal tragedy) by even qualified safety officers employed in well established units, indicate how inadequate is their technical information level. Ironically, all this prevails in spite of the fairly massive training and educational activities that go on in the country, which means that these programmes are to be made more and more need based.

Obsolete Machinery—Lack of Maintenance

Yet another dimension to the problems in the country, is the obsolescence of the machinery. Due to corrosive substances, tropical climate and poor maintenance, storage tanks and pipe lines get rusted. Parts are not replaced in time. Recently we have been hearing much about such instances. One of the alarming consequences will be that as time passes the number of accidental releases of toxic chemicals from such rusted containers may increase.

TABLE 7

Incidents of reportable industrial accidents due to factors which can be rectified through application of Egronomics principles

	Number of accidents analysed	ACCIDENTS ATTRIBUTABLE TO				Total due to the four causes
		Poor house keeping, poor maintenance of equipment, hazardous or defective arrangement of work	Unguarded or inadequately guarded machinery/ unsafe design	Non-provision of or non-use of personal protective equipment	Unsafe stacking loading/ handling	
		%	%	%	%	%
Building construction	62	3.2	14.5	8.0	12.9	38.6
Cotton textiles (Spinning)	838	17.7	6.2	—	28.5	52.4
Electrical motors and transformers manufacturing units	150	21.0	16.0	18.0	—	55.0
Engineering units	820	18.0	1.1	27.5	31.2	77.8
Ferrous foundries	603	20.0	1.5	8.2	33.0	62.7
Ferrous forging units	431	3.0	3.7	22.5	7.4	36.6
Fertilizer units	153	23.5	7.0	14.0	2.7	47.2
Jute mills	1156	5.9	9.3	—	27.3	42.5
Power presses, brake presses and power shears	561	10.8	49.5	—	—	60.3
Ports and docks	1357	20.4	—	—	53.4	73.8

(Source: Studies of Central Labour Institute, Bombay)

TABLE 8

Prevalence of health hazards in chemical plants attributable to neglect of Egronomics factors

Factory/ Process	Health hazard observed	Some of the identified contributing factors
1) Opium and alkaloid process	Absorption of benzene vapour	1) Inadequacy of local exhaust, as well as of natural ventilation. 2) Open extraction tanks not covered. 3) Defective handling due to lack of suitably designed process tank. 4) Non-availability of personal protective equipment.
2) Pesticide formulation units	High contamination of the work rooms with toxic pesticide dust and vapour	1) Inadequacy of local exhaust. 2) Poor maintenance of micro pulverizers. 3) Poor floor condition and poor storing of raw materials.
3) Viscose rayon	Exposure of carbon disulphide and hydrogen sulphide	Exhaust being ineffective due to spinning machines remaining open.
4) Caustic soda	Exposure to mercury vapour in the work rooms	1) Inadequate ventilation. 2) Non-provision of respirators to workers. 3) Poor floor conditions.
5) Storage battery manufacture	Exposure to lead dust and fumes	1) Non-provision of exhaust arrangements. 2) Non-mechanization of some critical jobs.

Fortunately, after the Bhopal tragedy, a survey of such equipments has been launched seriously.

Government's Promotional Efforts

With the back drop of all these problems, the Government of India has been organizing many activities to motivate the people, apart from framing statutes. The National Safety Awards and Shram Vir National Awards are schemes meant to motivate the managements and workers to aim at higher and higher levels of safety at work places. The laboratories set up at the Central Labour Institute, Bombay, for testing respiratory and non-respiratory personal protective equipment, help the indigenous manufacturers in improving the quality of their products. Realizing that one of the reasons for the reluctance of the workers to use PPE may be design defects, the Institute is also busy in designing acceptable alternatives. A disposable type of dust mask which has already been developed, and the ongoing efforts to design comfortable protective clothing to be worn in excessively hot work places, are worth mentioning. The managements are also motivated by projecting to them effective case studies (Table 9). Unfortunately, all these efforts are piecemeal and not well planned and coordinated.

TABLE 9

Impact of adoption of control measures

Stress factor/ pollutant	Control measure adopted	Impact
Carbon disulphide (Spinning halls of Viscose Rayon Unit)	Enclosure of the spinning machines-thereby improving the exhaust	Average concentration for 11 locations was reduced from 81.4 to 31.5 mg/M^3 (i.e. nearly 60% reduction)
Mercury (Cell House of Chloralkali Plant)	Improvement in ventilation	Average concentration for 9 locations came down from 0.84 to 0.35 mg/M^3 (i.e. nearly 60% reduction.
Radiant Heat (Forging foundry)	Aluminized overall worn	Heat rate elevation during work was reduced from 72 to 34 beats/min. (nearly 50% reduction)
Noise (Pharmaceutical factory)	Enclosing the granulating machine	Noise level reduced from dB$_A$ to 75 dB$_A$

(From the studies of Central Labour Institute)

Unorganized Sectors—Comprehensive Legislation

All the above discussions pertain only to the organized sectors. There are the unorganized sectors like the construction industry and agriculture, which are loaded with numerous safety and health problems. The accidents in the construction industry are often, of a serious nature. The workers in the industry being mostly migrant workers, not much attention seems to be paid by the employers, to their health and welfare problems. Considering the agricultural sector, the hazards therein are also fast growing. Even a couple of years ago, the annual consumption of fertilizers was 6.4 million tonnes and of pesticides 50,000 tonnes. These quantities are going to multiply fast. Large scale use of tractors all over the country, and adoption of mechanized threshing operations particularly in the northern states, pose additional risks to the agricultural labour. The low literacy level among the rural agricultural labour, and the consequent lack of awareness and appreciation of the hazards, intensify the occupational health and safety problems. It was reported in 1978 that 800 to 1000 serious thresher accidents were taking place annually in the northern states of Punjab, Haryana, Uttar Pradesh and Rajasthan alone, in which workers suffered serious hand injuries. Fortunately, the Government of India, is stated to be considering a comprehensive legislation on Safety and Health at work places, which will cover workers at all work places. This will, naturally, bring redress to the millions of workers in the unorganized sectors.

Research and Development to Become Need Based

While efforts are being made at government level, the scientists also have a big role to play. Normally, there is a tendency to undertake research in areas which are non-controversial. Quite often the research themes are on beaten track, with no relevance to the topical problems. It is a matter of regret that in spite of the scientific excellence in the country we still have to depend on external help for getting even apparently small problems solved. This has to change. If tangible results are to be obtained in the area of accident prevention and environmental protection, we have to develop indigenous expertize for scrubbing or otherwise treating the liquid and gaseous effluents. So far, industrial hygienists used to advise managements to flush out the pollutants into the general atmosphere through improved exhaust ventilation. We now realize how this may adversely affect the general population, particularly when highly toxic chemicals are involved. Ironically, a host of toxic chemicals are handled in the country, the long-term effects of which are not known, as was the case with MIC. The toxicologists may do well to prepare an inventory of such substances and take up these for studies. The industrial hygienists in collaboration with physiologists, may have to study the effect of multiple stresses, and make use of these in formulating permissible levels for exposure. Results can be ensured only if the activities are undertaken in a carefully planned and coordinated manner with critical evaluation from time to time. To carry out these, there should be a high level technical body in the country, empowered by law to give directions, and coordinate the activities of various research and development agencies.

Action Plan in Future

To sum up, the process of industrialization will continue, and there will be a phenomenal growth in the hazards to be faced. If the challenges to the health and safety of the workers and of the general population are to be met, a carefully drawn out action plan is to be adopted. This action plan has to:

1) Undertake a massive manpower development programme to build cadres of specialists like experts in testing of pressure vessels, pipelines etc., technicians trained in environmental sampling and analytical and diagnostic tests (these need not possess high academic qualifications, but should be well trained in techniques); occupational health specialists and industrial hygienists; research scientists in the areas of toxicology, and exposure standards setting.

2) Launch a crash programme to identify the total instruments need, and

arrangement for import (if necessary) to meet the immediate requirement, and for indigenous manufacture to meet the long-term need.

3) Establish a centralized data bank to maintain information on hazardous substances handled, the quantum handled and the locations where handled.

4) Bind the managements (if necessary through an ordinance) to intimate to the authorities technical details about the potentially dangerous points, and to carry out periodical safety audits.

5) Pressurize the managements to avoid holding unduly large inventories of hazardous substances.

6) Intensify the training and education (including retraining), of workers and supervisors.

7) Publicize through the media (using simple language) the dangerous properties of the hazardous substances handled in industrial pockets, and what people should do in case there is a warning that there has been an accidental leakage of a particular chemical.

8) Educate the rural population on the safe use of dangerous pesticides and fertilizers.

9) Ensure that research and developmental activities are undertaken on an aimed type basis (to solve specific problems)—establish a set up and empower it to direct and coordinate the above activities undertaken by different agencies.

VII

STATE OF THE ENVIRONMENT

27

Some Considerations on the State of the Present Climate and Environment of India—An Essay in 'Decline and Fall'

S. Dillon Ripley

It is worth stating that the most crucial aspect of environmental study today in the subcontinent is the interface between human culture and the environment. The essence of Indian culture stems from the pronouncements of the *Gita.* In this we are told of the essential respect that man must show for that on which were are dependent, the land, the air and water. All of India and its thousands of years of cultural evolution depend upon these essential elements. Too often, in the present day, technological triumphs seem to subsume the possibility that the prescriptions of the *Gita* might be ignored. In fact, however, such basic premises do not change and there is no possibility for us to ignore the lesson of respect for the environment.

Technology has not helped the foundations on which culture and human affairs depend. Massive exposure of the land, soil, water and air to the fruits of technological advance and development without regard for essential biological precepts can only hasten the degradation of what has been a fair land and a marvelous one for all manner and kinds of life. Examples are given from the fields of forestry, hydrobiology, and climatic degradation which transcend planters, politicians and philosophers alike. Much of this present course which is irredeemable can be diminished, if not controlled, by practical measures, but the effort involved will increase in expense every year in which they are neglected. It can only be hoped that a new, stricter discipline can be imposed by mankind itself to assure a viable future for the inhabitants of this land for, failing that, there is an inevitable timetable against which our efforts will likely prove fruitless.

In the early seventies, a group of American ecologists met with a group of Indian ecologists at my behest under a Smithsonian Institution grant. We met in Delhi for approximately a week and were much encouraged during the conversations to have observers from the Indian Government's Planning Commission present, in particular my late friend Mr. P. Pant who seemed to us to have a seminal and broad vision for the future. The interesting thing to me was that in 1972 there seemed to be relatively few ecologists, as such, in the Indian academic or institutional or bureaucratic framework. In addition to Dr. Sálim Ali, the originator of much of the ecological thought in India since the thirties, we had the pleasure of including in the group Professor Shivaji Rao from Andhra University in Waltair. He and I had had considerable correspondence about the threat to the Taj Mahal in those days from the proposed oil refinery designed for a few miles up-river. Sure enough, the oil refinery was finally constructed near Mathura and has indeed begun to contribute to the deterioration, through chemical action, of the marble surfaces of the Taj Mahal, India's most popular tourist attraction and a symbol of the art and culture of the nation. That conference, brief as it was, marked at least an inauguration of dialogue between Indian scientists and those abroad concerning problems which have become pervasive in subsequent years.

It has always seemed to me that the problems of biology and environment, whether in the tropical or temperate zones, transcend national boundaries. If we are biologists indeed, we should pride ourselves on being international citizens in respect to our research and publications. This idea is reaffirmed by the recent signing of an accord between the U.S.S.R. and the U.S.A. in order to renew joint environmental studies on acid rain, toxic waste, air pollution and endangered wildlife. I feel that it is a great mistake for scientists in any nation to adopt a parochial point of view about the work in which they are engaged if it occupies such a broad mainstream spectrum of interest as does contemporary tropical biology. Tropical biology is, in effect, a worldwide circum-equatorial discipline. Changing environments affect the climate of the rest of the world in due course.

Thus, the problems of which I speak are universal and worldwide. They can be considered anywhere in the tropical zone today and are as much a part of common concern as the presence of rain or sunshine, the winds, and the soil on which we all tread. Thus, paraphrazing the essence of the resources mentioned in the *Gita*, it is my hope to discuss problems in India in a totally objective manner.

In the forties, when I first began continuing research on the subject of ornithology in India with Dr. Sálim Ali, we were following up work done earlier by our British colleagues during the twenties and thirties. The formal Survey of the Fauna and Flora of British India had been very active in those days and resulted in large series of publications on vertebrates, invertebrates, and plants and trees from the Forest Institute and the Forestry Department of the time, through to the geology of the Geological Survey. Today much of the biological work of the time can be seen in a different context.

As the environment has become successively more vulnerable to human development and technology, so the work on environmental issues formerly confined to the biological surveys, chronologies of various kinds, and work in geology and the forest, has lost a purely scientific, theoretical basis. It now verges on becoming an applied science. No more can our research in ornithology, for example, be described as a part of pure research but should be closely allied to the whole subject of applied research. For indeed the crisis atmosphere in which we live today, extending across the broad spectrum of natural resources, presents an applied problem of the utmost moment to human endeavour and indeed survival.

It has always seemed to me that the lives in India of the tribal people and the country folk are inextricably intertwined with the lives of the animal and plant populations around them. Thus human survival is merely an aspect of animal and plant survival and all should be considered, measure for measure. It has been in the tradition, not only of the Judeo-Christian ethic but also the religions of the East, that human beings are set apart not merely as persons under the special benevolent protection of God, but rather as persons elect, above the animal and plant life around them. I suspect that the distinction in this regard is wearing rather thin today with the overwhelming pressures of human population on the one hand, and the degraded environment in which they live. The struggle for survival becomes one in which all animate life is involved and it is difficult to separate aspects of this struggle so that only humans, for example, with their inestimable God-given intelligence and protectability, can survive. We are all in it together.

In the forties when we were commencing our work, it was possible for us to visit untrammeled forests in places such as north-eastern Assam, the Bhutanese lowlands, the Nepalese *Terai*, and similarly many forested areas of central and eastern India. Flying in airplanes those days was done in prop planes. It was possible to coast over the forests at a low altitude, perhaps ten thousand feet, so that the expanse of the terrain below was clearly visible. For mile after mile one saw undulating patterns of green—the forest—not primeval, of course, but at least good, solid forest cover. Much of this forest was the result of plantation policies undertaken by the British-controlled Forestry Department of the late nineteenth century. Plantations of sal and teak, primarily in the mid-latitudes from Bihar and Bengal south to Tamil Nadu along the coast, and in the south-west gave the appearance of a uniform carpet of green. The rainfall in the forties averaged approximately twice as much in annual precipitation as it does today. I was astonished this past spring to hear an authority in Andhra Pradesh tell me that in the forties the annual rainfall in the Eastern Ghats amounted to 100 inches, and that in 1984, a typical one for this decade, the rainfall had declined to 43 inches annually.

What became a matter of exceeding interest to me, beginning in the forties, was the problem of the eventual spoliation of the environment. The single incident which triggered my mind was a visit to the proposed Kosi dam in eastern Nepal in 1948–49. The engineers were then hacking out huge parallel tunnels in the lowland hills of the area in preparation for a large high dam to be built there. After World War II there was a growing consensus of the need to create hydroelectric power plants capable of delivering kilowatts of power down in the plains, often along with adjunct dams for water storage. Although the siltation rate in the Kosi River is among the highest in the world, and although the speed of the water exceeds 18 miles per hour at times, the engineers were adamant in their insistence that this was going to be a marvelously successful dam which would do wonders to the emerging development of population centres in eastern India. They paid no attention to my comments, feeling that as a mere biologist I was unqualified to speak on issues of geology, rainfall, drainage, erosion and the like. However, it seemed to me inevitable that siltation would fill the dam within 20 years, that the erosion could only be greatly precipitated by the construction work involving, of course, camps for workers and timbering then in prospect, and that the benefits of the dam over the long haul would accrue only to the fulfillment of the contract of the engineers who had undertaken it. Indeed, in the last analysis, the engineers simply shook their heads and said "after all, we will have fulfilled our contract and we will not be here in 20 or 25 years to see the results." This philosophy of "spend the money, create the engineering miracle, and disappear" seems to still prevail, especially in the minds of the international banks and sources of funds for the creators of such plans. I often wonder whether the ghosts of those engineers of the 1948–49 period have ever visited the site of the Kosi Dam.

This 'development and progress' mentality imbues all of us with renewed optimism. Optimism in and of itself is a human trait which should be encouraged. The reverse, continual pessimism, is unproductive, and so optimism and creation of development plans must continue. But the question of the rationality of these plans should surely intrude at a certain stage and govern our optimism with a kind of measured, indeed an almost philosophic, scale of values. As the years have gone by and Dr. Sálim Ali's and my research has begun to culminate in the publication of volumes of our Handbook on Birds of the Indian Subcontinent, thereby fulfilling our original mandate to reconstruct and bring up to date the Fauna of the British India series, our own research has begun to be bent towards the environmental principles which meanwhile I had been studying and teaching at Yale University.

At Yale, a similar pioneering effort in environmental understanding had been led since the late thirties by my distinguished British colleague, Professor Evelyn Hutchinson. Joining with him in the post-war years in studies in ecological principles and in teaching and research, I found the commencement of a union between descriptive ornithology, the creation of texts on bird behaviour and ethology, and the problems of the occurrence and non-occurrence of birds in different environmental associations. Birds serve as splendid and tell-tale markers of species in the environment. Their presence denotes a certain combination of natural conditions and the subtleties with which one comes to understand this distribution is directly related to the successional stages of the environment. Of course we all know that today, but it is the rapidity of the succession stages which is staggering.

We have been able to begin to diagram changes in the environment as a by-product of the study of birds themselves. More recently we have managed to measure changes by periodic observations on a 25-year cycle of study by the same authors, possible of course with persistence, longevity and luck. In effect, we have been able to revisit sites and habitats which we had first begun visiting in the forties or even during and slightly preceding World War II.

Changes, once remarked, have been massive. The environment has not improved in the specific localities that we have visited. Rather, it has deteriorated. Where once flying over the forest it appeared like a continuous carpet of green, now patches of deterioration are widespread. Recently investigating a site in the upland areas of Orissa, we found that the forest is thin and insubstantial and, indeed, a kind of 'pseudo-forest' formed by mature forest plantations of sal or teak. Creation of forest monocultures depresses the richness of the environment. A solid stand of sal forest is biotically very poor. The continual, thoughtless destruction of so-called "miscellaneous forest," a fallacious term of the professional forester, implicitly denies the rich complex of forest species that miscellaneous growth implies. Replacing the complex natural system with an artificial monoculture produces, in effect, and ecologically depauperate system. The understory layers going down to the duff and peat and sub-soil strata are pathetically deficient in the rich variety of organisms, chemical supporting systems, and micro-organisms that should be there.

In the same way that the less observed aspects of the environment become depauperate, so the bird fauna diminishes in species variety. We find a significant decline in the richness and mix of bird species in such environments. A decline by 15 per cent is not unusual. This loss of variety in tropical and subtropical climates is an ecologically disastrous side-effect of creating a monoculture.

Tropical humid forest environments *per se* differ radically from the forester's monoculture. In the tropical forest a very large number of species is found in the environment, but the number of individuals of each species is far less numerous. In the high and middle latitude (temperate) environments the reverse is true. A limited number of species is present, each one of which has a large population. Thus in the Arctic, birds are limited in numbers of species but occur by millions in certain choice environments such as marine upwellings, for example, in the northern oceans. Thus man-induced restrictions of the numbers of species of plants leading to a monoculture in the tropics enhances the loss of species diversity and discourages the occurrence of a richer total environment.

Our habit of periodically revisiting research sites has led to many varied observations leading me to believe that we are at the point where these significant environmental changes can be directly measured in specific habitats. In general, the rapid disappearance of original forest all over India is alarming and easily observable. Present-day ecologists, of which there are now a welcome number in India itself, can attest to this by all sorts of strategems including the use of Landsat photography. The gross decline in forest cover has been stupendous in the last seven years. I noticed a quotation in one of the environmental publications of the Department of the Environment implying a loss of some 14 per cent of total forest cover for India in this time. Projected into the future, such a decline could be catastropic by the year 2000.

Statistics of this sort are currently repeated in journals and in summaries presented to the Department of the Environment. The net effect of these observations on the planning process of the government is still uncertain. Much of these sorts of statistics lie on paper, buried as it were within the paper and the type which carries the message. Will the important message of environmentalists be unheard? It can only be hoped that more progressive action would be undertaken outdoors, involving rolled-up sleeves and shovels, and plants to plant. This past spring I sat in at a session in New Delhi in which I was told an important part of the immediate planning process was the replanting of some 5 million ha of forest within the next three to five years. It is a statistic which sounds significant and positive, and I can only endorse such an utterance. I shall be waiting, along with many of my colleagues, to see what really has happened. A temporary moment of pessimism occurred during these discussions when one of the senior people involved asked my frank opinion of the use of eucalyptus as a plant to use in the reforestation process. I could only repeat a well-worn argument that should be now a part of known assumptions, namely that eucalyptus is an 'exotic' that cannot properly replace native forest trees either in economic value or environmental worth. Using it is, at best, a short-range solution—satisfactory for planting around human habitations as a source of fuelwood or for minor timber uses—but it is no answer to reforestation—indeed it would be a devastating solution.

The fact that there is any argument about this today beggars belief. Report after report has been written on the environmental costs of eucalyptus plantation. Any botanist will point out that eucalyptus is not a tropical plant of value for massive introduction into all parts of the tropical Asia. It does not contain the right mix, coming from an entirely different continent with a distinct and atypical environmental history. Rather by far, the sensible and somewhat commonplace argument should be upheld—namely, replant the native trees. There is no substitute for a native flora on its own ground.

Pros and cons can be put forward for such a simple argument under some circumstances, especially in parliamentary debates or in the planning process reprinted on paper. The fact of the matter is that a native plant assemblage is by far the best and most natural plant assemblage to plant and there can be no argument against it. Those who might argue that natural regeneration takes too long can be answered by noting that environmental health is not something that can be poured out of a bottle. A quickly regenerating eucalyptus monoculture is not worth a tenth of a maturing natural forest.

In my cycle of visits, Dr. Sálim Ali and I have been back to the north-east frontier to see the gradual deterioration of the only major stands of high tropical rain forest in the subcontinent. In the Mishmi Hills in 1946, we saw a virgin forest of towering and impressive quality and quantity, as rich as anything in that rainforest arc of mountains and riverine valleys ranging from the northeast across northern Burma, the northern Indochinese and Malaysian peninsulas, to southwest China, probably the richest biome in the Old World (the wonder of botanists and zoologists over the past two centuries). On our return visits we have seen only remnants of such a forest, with the best segments perhaps in the Namdapha area of the Tirap district, an area so relatively inaccessible due to climate and environment; one's devout and often unspoken hope is that it will remain simply because it is logistically and technologically so inhospitable to travel and development. Where the emerging tribal identities have taken over as in other parts of Arunachal and the adjacent frontier states, forest destruction proceeds rapidly with the concept of development and mimics evolutionary progress. By "mimic" I mean that the level of technology, chain saws, bulldozers, road construction, and all the appurtenances of civilization, tend far to outstrip the potential of the area itself or indeed the eventual happiness and salvation of the native population. The presence of assumed superior technological and civilized skills such as high-tech that culture can afford is hardly a substitute for a simpler agrarian life and the promises, inferior as they may seem in our eyes, of a humane, domestic, and rural level of activity. Surely there is a place in the world today for a properly organized, simple, rural community to exist without all the costs that come with increasing electrification, modern hospital computerized care, and the related travail which those of us in cities have to endure. I am in this sense not arguing as an Utopian purist of the last century, but rather perhaps as a visionary, of what can be considered to be a development for that same future of varieties of life-styles, each for their own environment and as rich in their own diversity as the despised "miscellaneous forest" of a forester's outmoded jargon.

In other of the states we have seen many of the same results. The vast resettlement of tribal people in Andhra Pradesh, for example, tribal Oriyas from Orissa and those from Tamil Nadu and the western parts of Andhra Pradesh into the areas adjacent to the Eastern Ghats have certainly not improved the environment in any sense, either for the environment itself or for the settlers. The desire of the government to settle tribals on their own land and create an agricultural sub-sector of the population may be utilitarian but is hardly constructive. The result is the perpetuation of the deforestation present everywhere in these areas and a continuation of the indigenous habits of cultivation associated with slash-and-burn agriculture. *Jhumming*, one of the persistent tribal habits associated with a shifting and mobile economy, is certainly no answer to a settled environment of farm and land holdings.

Yet *jhumming* persists. There were days this past cold weather season in Andhra Pradesh when, in the middle of a remnant of forest areas such as can still be found on the coffee plantations, the scent of burning along with fragments of carbonized leaves and bark from nearby *jhumming* operations came filtering down through the trees even as we worked. And we knew the forest burning could be ten or twenty miles away. There was a general pall in the atmosphere like smog caused by the persistence of burning all through the dry season. And yet *jhumming* serves no real purpose any more, for it is to a large extent reburning old burnt areas which are not being cultivated. It seems to be a ritual, like scratching an itch.

The decline in forest cover in a state such as Andhra Pradesh and its neighbours to the south and west can be directly related to the decline of rainfall and the resulting change in climate. The climate has become unbearably hot just as the declining water supply in coastal towns like Visakhapatnam has become an endemic problem. I was told on good authority that in 1945, four tribals who had taken refuge during a violent thunderstorm in the New Year's period were found the following morning clinging to a tree branches in which they sought shelter, frozen to death. By "frozen to death" I suppose one means "hypothermia" due to exposure, but surely this must also imply a lowered temperature. Certainly frost was not present at an altitude of 2200 feet above sea level in Lammasingi where the incident occurred. Perhaps the temperature got down to the low forties (Fahrenheit), but with winds and heavy rainfall—enough to produce a severe chill and death through exposure. The possibility of such an event taking place in 1985 seems remote, to say the least. Rather, the temperatures hover almost continually, even at night, in a range not lower than the fifties (Fahrenheit) and the possibility of violent wind storms accompanied by hurricane-like torrents of rain occurs only sporadically with off-shore, low-pressure cyclonic storms that sometimes plague the Bay of Bengal in post-monsoon times. If a heavy rainfall occurs now in the Eastern Ghats, it merely produces erosion, for the soil is not likely to be able to retain the moisture nor indeed can the series of silted-out dams do likewise.

There is much to be learned from the present situation and I have been delighted in recent months to come into contact with officials and members of departments who are fully aware of this serious situation, and conscious of the ecological principles which are involved. To these should be added numerous foreign ecologists and conservationists, notably members of the Centre Nationale de Recherche Scientific of Paris, who have established a strong position in studies of the ecology of the Himalayas, as well as a number of Americans concerned with research in Nepal and in association with various projects of the Smithsonian Institution and Zoological Survey of India.

The creation of a Department of Environment in India over the past few years has helped to focus attention on the fact that ecological research is central to environmental understanding. It is also an international concern, and no one should hesitate for even a moment to seize any opportunity to consult with experts on tropical biology and the supreme question of biological diversity, a crisis situation entirely brought on in my opinion by the effects of human intervention. Professor E.O. Wilson at Harvard, as well as Dr. Thomas Lovejoy of the World Wildlife Fund, U.S., have written extensively on the subject. All these persons are eager to help, and their knowledge is at our disposal here in India. Without a Green Army and a Green Revolution of action and understanding it probably will be impossible to stem the tide of increasing environmental deterioration in this marvelous country. That should be a cause beyond peradventure, beyond any national concerns of pride of place. It is certainly to be hoped that in years to come, everything will be done to ensure that India, as in so many other ways, excels in the restoration of the green canopy of life now reduced to some 13 per cent of the total forest cover of the past. Without guarantees of its speedy restoration the costs for all will be unimaginable. Where a Green Revolution in agriculture has virtually succeeded in India, we now need a Green Revolution in ecology, and scientific understanding with appropriate action. Without it, the studies of the River Ganges, the studies of afforestation, the studies of desertification, all will fail, for understanding and action are of the utmost priority and the essence of future survival.

SELECTED REFERENCES

Berreman, G.D. Himachal: science, people, and "progress", *IWGIA* (Document 36), Copenhagen, 1979.

Gadgil, Madhav. Conserving biological diversity. In: *Ecology in Practice* (Eds.) DiCastri, Baker and Hadley, Tycooly, International Publ., Dublin, pp. 485–491, 1984.

Gadgil, Madhav. Husbanding India's natural resources: the tradition and the prospects. In: *The Canvas of Culture: Rediscovery of the Past as Adaptation for Future*, (Ed.) W. Dillon, Smithsonian Institution: Washington, D.C. (In Press).

Gadgil, Madhav and V.D. Vartak. The sacred groves of the Western Ghats in India. *Economic Botany* 30: 152–160, 1975.

Lovejoy, Thomas E. Conservation beyond our borders. *The Nature Conservancy News* 29: 4–7, 1979.

Prodon, Roger. Sur la composition et la biogeographie de L'Avifaune du Ladakh (Inde). *Acta Biol. Mont.* 4: 573–581, 1984.

Ripley, S. Dillon. *Paradox of the Human Condition*. Tata McGraw-Hill, Bombay. Reprinted (1985) Smithsonian Institution, 1975.

Ripley, S. Dillon. Conservation and preservation in India. In: *The Canvas of Culture*, (Ed.) W. Dillon. Smithsonian Institution: Washington, D.C., 1985 (in Press).

Wilson, E.O. The biological diversity crises: a challenge to science. In: *Issues in Science and Technology*. National Academy of Sciences: Washington, D.C., pp. 20–29, 1985.

28

Environmental Management in Asia and the Pacific and the Role of Science and Technology

ESCAP

Introduction

Over the past decade, the nations of Asia and the Pacific region have been particularly concerned about the quality and sustainability of the region's natural resources. Over 56 per cent of the world's people live on only 31 per cent of the arable land. By the year 2000 almost as many people will live in Asia and the Pacific region as lived on the face of the earth in 1970. National governments in the region realize that they have to develop their economies to meet the needs of a population already living in poverty and expected to grow substantially, and at the same time protect the natural resource base on which this economic growth and physical health depend.

There has been wide recognition that economic and social development of the region can be sustained only if environmental concerns are integrated with the development process. The problems associated with the process of this integration can be appreciated better by studying the trends of resource utilization, their impact on environmental quality and stocks, and responses of different governments of the region to this formidable challenge.

The environmental issues received a tremendous fillip when the United Nations General Assembly, at its twenty-third session, decided to convene a United Nations Conference on the Human Environment in 1972. Further, the Economic and Social Council and the General Assembly stressed that environmental policies should be considered in the context of economic and social development with special reference to the needs of the developing countries. As an activity preparatory to the Conference, the Panel of Experts on Development and Environment met at Founex, Switzerland from 4 to 12 June 1971 and discussed that issue in the context of the urgent needs of the developing countries. The Panel recommended that environmental considerations should be an integral part of the economic and social development process and invited the regional commissions to discuss the issue in detail. As a consequence, the regional commissions, in particular, played a significant role in the preparatory process for the Conference and the Economic and Social Commission for Asia and the Pacific (ESCAP) has, since then, continued vigorous efforts not only in promoting environmental programmes in the countries, but also in incorporating environmental dimensions in its work programme. More recently, UNEP commemorated the tenth anniversary of the United Nations Conference on the Human Environment in 1982 by organizing its session of special character and adopted Nairobi Declaration and Action Programme on the Environment. It was suggested that ESCAP should act as the regional focal point of the United Nations System for the effective implementation of the Nairobi Action Programme.

The concern for integration of environmental considerations into the development process in the Commission dates back to 1973 when the Economic Commission for Asia and the Far East (ECAFE) made several recommendations encompassing different sectors for the management of human environment on a proposal to launch an Asian Plan of Action for the Human Environment. In the eighties, resolutions 202 (XXXVI) on regional cooperation on environmental policy, management and law and 224 (XXXVIII) on incorporation of environmental consideration into the economic and social development activities of the Commission were adopted to effectively deal with the environmental problems in the region. More recently, to have a better understanding of the relationships involved, the Economic and Social Commission for Asia and the Pacific prepared a report on the state of the environment for Asia and the Pacific for presentation at the Ministerial-level Conference on Environment for Asia. The Ministerial-level Conference on the basis of this report, adopted Declaration and Framework for Action Plans for the Management of the Asian Environment. Further, the report provided an important input for formulating country-specific action plans for the management of Asian environment and for assisting the countries of the region in their efforts to promote sustainable development. The Commission recently reviewed the implementation of the action plans in pursuance to the ministerial-level meeting and found that the countries have taken several positive measures for environmental protection and improvement.

Population, Resources, Environment and Development Trends

Population, resources, environment and development are inextricably interlinked. The demand for natural resources and environmental amenities in the ESCAP region has continued to increase sharply for the reasons of rapid population growth, relatively impressive rate of growth of economy and unprecedented technological developments. While these factors will raise the demand, the supply of natural resources (even renewable resources) may not increase appreciably and may even decrease in absolute terms. What is more, the quality of natural resources may continue to decline, as has been observed in the recent past.

The population of the region stood at 1.36 billion in 1950. Between 1975 and the year 2000, an increase of population of 1.13 billion is estimated from 2.27 billion in 1975 to 3.4 billion in the year 2000. The increase is enormous by historical standards and is approximately equal to the total Asian population in 1950. That is to say, from 1950 to 2000, the increment of population amounts roughly to 2.25 billion or over 165 per cent of the total regional population in 1950. This is an unprecedented demographic event. Its impact on the biological and socio-economic systems of the region will be substantial and would be felt a long time after the year 2000, even if, abruptly, there were to be no further population growth thereafter. Further, the proportion of working age population in the total will increase from 56 per cent in 1975 to 63 per cent in 2000, which implies not only demand for more resources but also need for more employment. It is estimated that mere transformation of human populations into productive human capital will take away about a third of total investment resources.

The terrestrial ecosystem is encountering serious problems of soil erosion, deforestation, waterlogging, salinity and aridity. Deforestation is taking place at a rate varying between 0.6 and 2 per cent. The area under forests is expected to be reduced by half by the year 2000. As an index of soil erosion, approximately 70 per cent of the global silt and sediment load is carried by the Asian rivers amounting to some 14 billion tons per year. About 82 to 90 per cent of the soils in the region have serious limitation for agricultural productivity. The total area most extensively affected by salinity is estimated to exceed 5 million ha, which is equivalent to more than 16 per cent of the regional land area. Chemical degradation of the soil due to natural and man-made causes has also been observed in several countries of the region. The contribution of the region to the global desertification problems has been estimated to be 46 per cent in terms of land area and 60 per cent in terms of population. Pasture lands have shown acute stress due to highest density of cattle, sheep and goat population in this region. Loss of soil productivity and desertification are driving millions of people in the region into a state of misery, poverty and landlessness and turning them into ecological refugees, who need to be rehabilitated and given fruitful employment opportunities.

Similarly, the marine environment and related ecosystems are also afflicted with serious environmental stress. The mangrove forests, which now cover about 8 million ha, have been seriously depleted over the years for reasons of over-exploitation for timber, pollution from domestic and industrial effluents drainage and siltation, land reclamation and natural calamities such as hurricanes. Coral reefs have been devastated as a result of mining for construction materials, extraction for souvenir and ornamental purposes and sedimentation and pollution from water run-off and drainage, the fish catch per inhabitant which increased by 26 per cent from 1960 to 1980 is likely to increase by only 3 per cent over the next 20 years. Most of the aquatic resources and ecosystems are polluted immediately downstream of urban centres, industrial and port areas as a result of discharge of untreated and partially-treated industrial and domestic wastes into the water-bodies. Higher concentration of heavy metals have been recorded in several rivers and coastal waters in many countries including Australia, China, India, the Philippines and Thailand. Tin and sand mining from the off-shore coastal areas have adversely affected the marine environment. Oil pollution has assumed serious problem in the seas of the region as much of its areas fall on the tanker-traffic routes. Urbanization has also created problems of terrestrial and aquatic ecosystems as lack of sanitation and water supply facilities, air and water pollution, shrinking open spaces and recreational areas, traffic congestion, waste disposal and acute shortages of shelter are tending to overstretch the environmental amenities beyond their carrying capacities with attendant problems of poverty and human health. Air pollution in major cities has increased over the years and a corresponding relationship between air pollution and incidence of respiratory diseases has been observed in the urban areas.

Poverty and the consequent stress on the environment adversely affect the development of human resources by impairing health and productivity. In the least developed countries, the per capital dietary energy supplies had gone down from 1967–69 through 1978–80. In another four developing countries, India, Sri Lanka, Thailand, and Solomon Islands the dietary energy supplies remained constant over the period. The actual number of people suffering from malnutrition in nine Asian countries according to the FAO was about 250 million in 1969–71 and this number increased to 280 million in 1972–74. The same relationship which exists between nutrition and poverty also holds between life expectancy and poverty. In general, the greater the extent, spread and intensity of poverty, the higher is the infant mortality and the shorter is the life expectancy. About 5 million children die globally every year of diptheria, diarrhoea, whooping cough, measles, polio and tuberculosis. Sixty per cent or 3 million of these deaths occur in Asia. Inadequate water supplies for drinking and other consumptive uses and inefficient or non-existent sanitation facilities are another aspect of poverty in its relationship to environmental health. It has been estimated that 80 per cent of the diseases in the developing world are directly attributed to unsafe water and poor sanitation. The magnitude of water and sanitation inadequacies is staggering. In 1983, in the urban areas of the region, 33 per cent of the people lacked clean water and 52 per cent lacked adequate sanitation. Not surprisingly, the situation was much worse in the rural areas where 56 per cent of the people were without clean water and a whooping 91 per cent were without adequate sanitation. It is clear that the percentage coverage for sanitation lags far behind the coverage for water supply. The estimated number of people suffering from water-related diseases is immense. At any one time in the world there were probably 500 million people with trachoma; 250 million people with elephantiasis; 200 million with bilharzia; 160 million people with malaria; with onchocerciasis (river blindness). Approximately 50 per cent of the people suffering from the above diseases except for those with river blindness are found in Asia at any one time.

As for development trends, projections were made of the gross national product from 1975 through 2000. It was estimated that the gross national product which was $ 697 billion in 1975 would increase by the year 2000 to $ 2,023 billion, an increase of 290 per cent. Further the share of value added by industry registered a general increase everywhere, in some countries in an outstanding manner indicating transformation of production processes into more capital and technology intensive. Indonesia showed an increase of 300 per cent from 14 per cent in 1960 to 42 per cent in 1980. In Malaysia and Singapore, it went up from 18 to 37 per cent, in Thailand from 19 to 29 per cent and in the Philippines from 28 to 37 per cent. The Republic of Korea and Papua New Guinea were other outstanding examples where the ratio went up from 20 to 41 per cent and from 11 to 30 per cent respectively.

Inter-relationships Between Population, Resources, Environment and Development and Role of Science and Technology

It may thus be seen that the quality of environment, the productivity of the terrestrial and aquatic resources and the problems of human health continues to be under severe threat for reasons of three broad factors at work. First, the population, that increased by 8 billion from 1960 to 1980 is likely to increase by 1.3 billion during 1980 to 2000. Second, more important than population, is the expected continuance of annual growth rate of economic activity at around 5 per cent, doubling the demand on natural resources every 15 years or so. Third, the process of production inevitably becomes more capital and technology intensive. It has however been seen that population growth and increase in per capita production had much less prominent impact in resource degradation than the impact of the technological processes and changes. It has been estimated that increase in degradation of resource base and environmental quality in the U.S.A. between 1949 and 1968, which ranged from 200 to 2000 per cent depending upon the pollutant, was attributed only 12 to 20 per cent due to population growth, 2 to 40 per cent due to increase in per capital production but more than 40 to 90 per cent as a result to technological transformation. Thus, if the impact of technology for production on the environment in the past is an indication of its potential adverse implications, careful technology planning with due considerations to environmental aspects of it must be an essential pre-requisite for any development process.

The key issues underlying the linkages between population, resources, environment and development may be summarized as follows:

a) Outer limits to growth and development arising out of inadequacies of resources of the environment are real and substantial; but they are quite elastic. Their rigour can be substantially mitigated in the long run by adopting appropriate development strategies, scientific and technological innovation and human resources planning;

b) While scientific and technological breakthroughs might shift the resource exhaustion schedules to a long time frame, the immediate and short-term tasks are to make substantial adjustments and improvisations in coping with the resource constraints. It is in this regard that the 'inner' limits arising out of political processes, social rigidities, attitudinal archaism and institutional irrelevance seem to exercise their influence more rigorously in the developing countries than in the developed countries. A realistic analysis of the inter-relationships is best carried out on a specific country by country basis for identifying the local outer limits and assessing their relative strength vis-a-vis the inner limits;

c) The constraints in resolving the underlying correlation of population, resources, environment and development are: the inadequacy of capital; the spectre of diminishing returns; the miasma of poverty and consequent human degradation; and the uneven spread of technologies and the barriers to their transfer to the developing countries. A major development problem everywhere is paucity of investment resources which, in association with growing population, causes diminishing returns in production. The scarcity of capital and the natural resource degradation are responsible in a large way for the spread of poverty.

Thus, diminishing resource base, increasing population, need for continuously enhanced standard of living, accompanied by the problems of capital shortage, the operation of diminishing returns arising from imbalances in the capital structure, absolute poverty of large numbers as a thoughtless waste of human potential, international and regional inequalities, the growing need for and increasing difficulty in introducing environmentally sound and appropriate technology, and inadequate flow of assistance to the developing countries—all these define the mutual interaction of population, resources, environment and development.

Scientific and technological development and planning would thus be an important component in mitigating the problems of environmental and natural resource degradation. Such technology planning should not merely cover the physical technology for producing goods and services and reducing environmental pollution, but should aim also at the mitigation of 'inner limits' rich the enhancement of human skills, upgradation of physical and institutional capital and improvement of natural resources stocks. This calls for a harmonious integration of technology for development and environmental technology in order to ensure sustainable development over a long run. In order to affect such an integration, the following considerations may be kept in mind:

a) Resources of the environment are fully the resource for the development;

b) Environmental problems associated with development can be mitigated to a large extent, by the use of environmental technology. This is especially true of the developing countries which, being largely in the initial stages of development, can pre-empt environmental problems from arising (in the general form of the pathology of the development process) by adopting a strategy of development which incorporates the environmental dimension from the very beginning; and

c) Even though development and environment are integrated in terms of both function and strategy, technology as applied in practice to the development process may have adverse impacts on the environment. These have to be minimized through an appropriately devised environmental technology and related policies. These can be achieved through technology planning, which encourages the use of technology that has the most benign impact on environment in the process of development. This concept can be expressed into the following equation:

Technology for development + Environmental technology
= Technology for sustainable development

To put it more accurately, environmental technology is viewed as an operator which transforms technology of development into technology for sustainable development.

Both hard and soft technologies are needed to transform technology for development into technology for sustainable development. The next section deals previously with hard technologies concerning environmental monitoring and research, resource conservation and pollution control. Resource conservation technologies cover technologies for preventing deforestation, soil erosion and desertification, while pollution control technologies include containment of water, air and solid waste pollution. Even though, soft technologies are equally, if not more important and deal generally with planning and assessment, legal and institutional measures, information and education, training and public participation, these have not been covered due the paucity of space and time.

Environmental Science and Technology in Asia and the Pacific

The most important concern regarding resource conservation in the region relates to conservation of terrestrial and aquatic ecosystems. In this context, preventing deforestation and promoting afforestation, arresting soil degradation with proper land and water management, combating desertification with the promotion of anti-desertification technologies and conserving endangered species of plants and animals are the major problems, the technologies for which are fairly well established and are receiving high priority in the region. However, pollution control technologies in general are continuing to evolve in the region. Extensive research and development have resulted in the development of technologies for prevention, control and recycling of the pollutants of water, air, noise and solid wastes. In this context, environmental technologies developed and used for air, noise and solid waste pollution control in the region are relatively of recent origin and public awareness about these technologies has only just begun. Consequently, the know–how of monitoring and control technologies for air, noise and solid wastes is seriously deficient. In the few instances where the technology is available, non–availability of expertise or sometimes raw material (like special steel for high temperature etc.) hampers its use or expansion. On the other hand, technologies for water pollution control, supply and sanitation are fairly well developed in the region.

Environmental Monitoring and Research

It is necessary to have access to consistent and accurate environmental data before action is initiated for environmental amelioration. Environmental monitoring and research should, therefore, be an integral part of any environmental programme. Monitoring of the environmental and natural resource parameters is necessary for ensuring optimal use of these resources. Monitoring and research on the environmental and natural resources in relation to their possible use will not only facilitate the best use of these resources, but also give an insight into their carrying capacity and sustained utilization. It also permits the possibility of change and reversal of decision regarding the allocation of resources during mid–course evaluation of the development programme and project. Comprehensive environmental monitoring and research incorporating the interlinkage among different parameters of natural resources such as land, water and air on one hand and their impact on the health and well-being of the people on the other have not been generally undertaken in the region, although attempts have been initiated in Japan and the Philippines to evaluate the inter-relationships comprehensively. In most other countries, some water and air pollutants are being generally monitored.

Natural Resource Monitoring and Research

Efforts have been made in several countries of the region to monitor the quality of natural resources such as soils, forests, deserts etc. Utilization of aerial photography, satellite imagery and remote sensing for monitoring and research has been on the increase. While global studies have been instrumental in focussing on issues of environmental and natural resource degradation, many countries of the region have established remote sensing institutes but are yet to use these modern technologies for natural resource planning in the region. Research and monitoring of forestry is being carried out in almost all the countries, but there is need for systematic data collection and conduct of relevant research. Australia, China, India and Pakistan are engaged in significant research on desertification, but in some of the developing countries, translation of research results in actual field conditions has been rather deficient.

Pollution Monitoring and Research

Almost all the countries have initiated significant aquatic quality monitoring activities at the national level. The present status of water quality monitoring in the ESCAP region is indicated in Table 1. Systematic water quality monitoring, as practised in the industrialized countries, has not yet been possible in many countries in the ESCAP region. However, a number of specific water quality monitoring programmes have been carried out in the region over periods from one to several years. From almost an insignificant number of monitoring stations in the early seventies, countries of the regions have established several hundred sampling points. Now China has 650 monitoring stations, Hong Kong 314, India 240, Malaysia 317, and Republic of Korea 205. There is a continuous upsurge in the establishment of monitoring systems in the region.

Ambient concentrations of a number of different air pollutants, like sulphur dioxide, particulate matter, carbon monoxide, hydrocarbons, sulphation rate, nitrogen oxides, etc., are being monitored in Australia, China, India, Indonesia, Japan, Malaysia, the Philippines, Republic of Korea, Singapore and Thailand. Monitoring activities, however, need to be strengthened in several countries. More importantly, environmental impact monitoring which would demonstrate a clear link between air or water pollution and human health effects needs to be promoted. Further, research on technological options in the containment of environmental pollution has yet to be seriously undertaken in the region.

Deforestation and Desertification Control

The causes and consequence of deforestation and desertification vary widely among the countries of the region. Consequently, the technologies employed by the member countries also differ significantly. Although, technological measures to combat these problems are well known, their implementation and impact on the containment of these problems are a fair indicator of the relative success of these technologies.

The typical kinds of problems encountered in the ESCAP region (and the countries most affected) include:

1) Deforestation (India, Indonesia, Malaysia, Nepal and Thailand);

a) Biological oxygen demand
b) Chemical oxygen demand
c) Total organic carbon
d) Suspended solids
e) *Escherichia coli*
f) Dissolved oxygen
g) Chloride, ammonia, nitrite, nitrate, orthophosphate and alkalinity
h) Flow rates are measured in a few streams
i) Major cations and anions; heavy metals, synthetic organics, biologic parameters for bottom sediments
j) Nitrate, phosphate, turbidity and heavy metals
k) Only limited samples taken over several years plus some chemical constituent
l) Salinity, total solid, nitrogen, phosphorus, heavy metals and pesticides.

2) Aridity and semi-aridity (Australia, parts of India and Pakistan);

3) Receding grasslands (Afghanistan, India and Australia);

4) Shifting cultivation and overcropping (Bangladesh, India, Indonesia, Philippines, Sri Lanka and Thailand);

5) Waterlogging and salinity (Afghanistan, India and Pakistan); and

6) Hydrological quandry in the river valleys (Bangladesh).

In order to combat the problem of deforestation and desertification, several countries have adopted both engineering and ecological technologies (Table 2). However, the emphasis is presently to encourage tree plantation

TABLE 2

Summary of positive measures and action programmes to control deforestation and desertification

AFGHANISTAN
- — Ecological mapping project
- — New laws on land holding, grazing, forests etc.
- — Afforestation or green belt around Kabul

AUSTRALIA
- — National programme of reforestation including stress on soft wood plantations
- — Incentives for private reforestation efforts
- — Improve drainage and new irrigation scheme along Murray River
- — Dust control programme at Broken Hill and Alice Springs
- — Protection of vegetation at Ayers Rock
- — Rehabilitation programme at Ranger uranium mine
- — Rabbit warren eradication programme

BANGLADESH
- — Country wide afforestation programme covering 400,000 ha
- — Village wood-lot programme in 68,000 villages
- — Resuscitation of dead and dying rivers
- — Food for work programme for special canal digging and anti-desertification works

CHINA
- — Massive afforestation programme on 28 million ha
- — Extensive programme for watershed development in critical areas
- — Agro forestry coupled with rural development activities
- — Subsidies for tree plantation
- — Sand stabilization by sand block forest belts on the periphery of oases; protective forest networks within the oasis and establishment of a 'contain-sand-cultivate-grass' area
- — Establishment of '*kulum* grass' on stabilized and semi-stabilized sand dunes and rational grazing by livestock
- — Management and utilization of existing resources, particularly along the rivers and in lake basins, land levelling and construction of reservoirs
- — Plantation of trees and shelter belts along the railways and highways study of soil characteristics as influenced by pastures, legumes, water application and levelling

INDIA
- Reforestation of 2.1 million ha
- Proposed 5 million ha afforestation programme on wasteland every year
- Agro-forestry
- Subsidies/tax concessions on natural resource conservation projects
- Desert Development Programme in 19 districts
- Drought Prone Areas Programme in 73 districts
- Rajasthan Canal Irrigation scheme of 650 km stretch
- Eco-development Task forces for Rajasthan Desert and Himalayan Ecosystems
- Operational Research Programme and Lab to land Programme on Shelterbelts, water and soil management and rodent control
- National Ravine land reclamation, salinity and alkalinity control and soil conservation programme

INDONESIA
- National Reforestation and Regreening Programme of 19 million ha.
- Integrated Watershed Development Projects
- Transmigration Project
- Programmes of Insurance Against the Risk and Effects of Droughts

ISLAMIC REPUBLIC OF IRAN
- Sand shift control demonstration projects at Ahwaz and Haresabad
- Sand Dune Stabilization Project over 2.4 million ha
- Control of sand dune by aerial mulch spraying over 75,000 ha
- Biosphere Reserve Pilot Project in Turan covering an area of 20,000 sq km
- Co-ordinated Research on desertification processes and strategies at the Institute of Desert Studies, University of Tehran

NEPAL
- National Afforestation and Conservation and Improvement of Forests Programme
- 13 Integrated watershed development and soil conservation projects during 1980–1985
- Integrated Rural Development Projects

PAKISTAN
- National Accelerated Programme of Waterlogging and Salinity Control
- Water Sector Development Programme
- Livestock development in Thar Desert of Sind, reclamation of wind eroded lands, stabilization of sand dunes and control of hill torrents under Barani Area Development Agency (BADA)
- Tile Drainage Project under Drainage Reclamation Institute of Pakistan (DRIP)

PHILIPPINES
- Forest Ecosystem Management covering reforestation of 750,000 ha in 1980–85
- Greening of Metro Manila
- The Tree Planting Programme
- The Ipil—Ipil Programme, preservation of mangroves stands and integrated municipal and barangay nurseries and subsidies/tax concessions on reforestation programme
- Kaingin management programme to stabilize shifting cultivators in one area by providing them with a 'forest occupancy permit' and helping them with improved production technology

- Family approach reafforestation programme, which enables each family to acquire 0.5 sq km of open land for free planting for a period of two years
- Projects under National Soil Erosion Management Committee

THAILAND

- Re-forestation of denuded areas and promotion of tree plantations with fast-growing tree species
- Acid and saline soil improvement project
- Hilltribe resettlement project
- Irrigation, drainage, flood control, watershed management and conservation and land reclamation project of the Royal Forestry Department
- Prevention of agricultural practices in steep slopes

---

and reforestation programmes, agro-forestry and related activities such as forestry education and extension campaigns. The pace of these programmes have undoubtably intensified during the eighties. In fact, these efforts have now become a cornerstone of all anti-deforestation and desertification programmes. In China, 28 million ha of land have been afforested, of which 6 million ha are state owned. India has reforested 2.1 million ha and has embarked upon a programme of massive reforestation. Indonesia has afforested 1.9 million ha. In the Philippines, rate of afforestation has increased from an average of 7,600 ha/year by end 1975 to 61,700 ha/year during 1976–1982. Such accomplishments are remarkable by any standards. Although, Bangladesh, Nepal, Pakistan and Thailand have modest achievements so far, their governments are giving increasing attention to this matter. Despite these successes, the rate of deforestation in most countries far exceeds the rate of afforestation. Only in the Philippines in recent years or possibly in China, have afforestation programmes been able to catch up with the rate of deforestation. This imbalance is a major cause of concern in the region and vigorous efforts are necessary to amend the situation. It is, however, encouraging to note that increased afforestation efforts are afoot in almost all the countries to combat desertification.

WATER POLLUTION CONTROL

In choosing an appropriate control technology for water pollution control, attempts have been made to minimize not only the quantity of polluting materials being discharged but also to reduce the effect of discharged pollutants. The final choice in the adoption of a particular control technology needs to specific to the situation in need of control. An overview of the technical strategies for water quality management followed in the countries of the region indicate the use of a mix of different technologies as given in Table 3. A more detailed description of the waste water treatment technologies for dealing with point sources of water pollution is given in Table 4. The selection of an appropriate pollution control technology is generally based on the combination of economic, technical and social criteria. In this respect, technologies, which are relatively cheaper, which the users can afford and maintain and which the local authorities are institutionally capable of operating are the most appropriate and feasible for the ESCAP region.

TABLE 4

Waste water treatment technologies

Material to be removed for converted	Unit process	Commonly used processes in ESCAP countries
Non-degradable materials		
Coarse solids	* Screening	X
Suspended solids	* Sedimentation	X
	* Coagulation and Flocculation	X
	* Filtration	X
	* Flotation	
	Centrifugation	
	Cyclone	
Dissolved solids	Distillation	
	Electrodialysis	
	Reverse Osmosis	
	Dialysis	
	Ion Exchange	
	* Neutralization	
	* Oxidation/Reduction and Precipitation	
Degradable organic materials	Aerobic biological treatment:	
	Activated sluge	
	Biological filters	
	* Biological disc filters	
	* Oxidation ditches	X
	* Oxidation ponds (Facultative)	X
	* Aerated lagoons	X
	Anaerobic biological treatment:	
	* Anaerobic digestion	X
	* Anaerobic contact	
	* Anaerobic lagoons Absorption	
	* Activated carbon	
Sludges	Concentration:	
Inorganic and organic	* Clarifier thickening	
	* Gravity thickening	
	* Flotation Dewatering:	
	* Drying Beds	X
	* Lagoons	X
	Filtration-gravity	
	-vacuum	
	-pressure	
	Centrifugation	

Organic	Digestion:	
	Aerobic	
	* Anaerobic	
	Heat drying and combustion:	
	Heat drying	
	Incineration	
	Wet oxidation	
Liquid effluents and solid residuals	Final disposal:	
	Land fill	X
	* Fertilizer	X
	Stream discharge	X
	Sea discharge	X
	* Irrigation:	X
	Underground disposal	

Note: The technologies more appropriate to developing countries are shown with an asterisk (*).

Urban water supply systems rely mostly on surface water sources which are routed through conventional coagulation, clarification, rapid gravity filtration, and chlorination treatment plants. The selection of rural water supply follows the rationale of low-cost approach. Groundwater from perennial springs, wells or boreholes is by far the most practicable choice. Withdrawal of groundwater by low-cost tubewells (mostly shallow tubewells, and bamboo tubewells using handpumps) are the most commonly used technologies in the developing countries of the ESCAP region. In cases where surface water must be used, pre-treatment with a horizontal flow coarse media filter, following by slow sand filtration helps to ensure compliance with both physical and bacteriological water quality-standards.

The available sanitation technologies can be broadly classified into five types of households systems and four community systems. The household sanitation technologies are pit latrines, pour-flush toilets, composting toilets, aquaprivies and septic tanks. The community sanitation technologies in use are bucket latrines, vault toilets with vacuum-cart collection, communal facilities and central sewerage systems.

AIR POLLUTION CONTROL

A variety of air pollution control technologies are available for handling particulates, dust, sulphur dioxide, nitrogen oxides and hydrocarbon emissions. A brief list of the available technology is given in Table 5.

SOLID WASTE MANAGEMENT

Solid waste disposal is a growing problem in the region. It is primarily because more than 56 per cent of the global population resides in this region and 20 per cent of the global economic activity is contributed by the region.

TABLE 5

Air pollution control technologies

Pollutant	Process and equipment	Commonly used process in ESCAP countries
Particulates and dust	● Settling chambers	
	● Centrifugal or inertial separators	
	— cyclones	X
	— baffle chambers	
	● Scrubbers and wet collectors	
	— air washers	
	— wet filters	X
	— spray towers	X
	— centrifugal or inertial scrubbers	
	● Filters	
	— viscous or oil wetted filters	
	— dry filters	
	— cloth filters	
	— high efficiency interception filters	
	— sintered metal and porous ceramic filters	
	● Electrostatic precipitators	
	— tubular and plate type	X
	— two stage type	
	● Sonic agglomerators	
Sulphur dioxide, nitrogen oxides and hydrocarbons	● Scrubbing	
	● Absorption	
	● Oxidation	
	● Catalytic conversion	
	● Control at source (control or excess air and sulphur content of fuel, etc.)	X

Source: ESCAP, Technology for Development: Environmental Aspects. (Bangkok, 1984) (Manuscript).

There has been an increase of over 130 per cent in the agro-industrial crop production and over 450 per cent in the manufacturing gross domestic product between 1960 and 1980. According to one estimate, there would be almost an 80 per cent increase in the volume of solid waste production over the next 20 years. The technologies used for disposal are sanitary landfill, energy recovery from refuse such as direct combustion, incineration, mechanical processing, pyrolisis and bio-conversion; refuse composing and organized scavenging and recycling. Sanitary landfill is practised throughout South and South-East Asia. Although direct combustion is more systematic and complex in some advanced countries, it remains a relatively simple affair in the developing countries either with the burning of combustible materials or use of cakes of animal manure (cow dung) together with other organic wastes, drying them in the sun and burning them as fuel. The latter is practised throughout South Asia and some parts of South-East Asia. Incineration is however practised in more affluent countries of the region such as Hong Kong, Japan, Republic of Korea and Singapore. The bio-conversion of municipal solid wastes is mostly carried through anaerobic digestion with the production of biogas. In China and India, biogas is extensively produced primarily with animal manure. In the Philippines, the installation of biogas digesters in markets and slaughter houses have been recommended to prevent filth and poor sanitation problems. Bangladesh, Nepal and Sri Lanka are increasingly planning to use biogas through bio-conversion of municipal solid wastes. Refuse composting for use as soil conditioner, fertilizer and bulking agents for land reclamation etc. is practised in China, India, Republic of Korea, Philippines and Thailand. Organized scavenging for the recovery of re-usable materials such as plastics, paper and glass and their resale to end-users is a common phenomenon in the countries of South Asia specially Bangladesh, India and Sri Lanka and of South-East Asia such as Philippines and Thailand. In Manila, Philippines, a government sponsored project called 'Resource Recovery Project' includes the recruitment of scavengers as 'ecology aides' or 'eco aides'. In Colombo, Sri Lanka, municipal workers spend up to 20 per cent of their time in salvaging saleable materials from the refuse. In Bangkok, Thailand, a worker is able to earn $ 6,000 to $ 9,000 per year from such an activity. However, solid waste disposal and recycling form only a fraction of the total solid wastes generated and such facilities are particularly promising to bring greater economic benefits in future.

Concluding Remarks

There are generally two pathways of science and technology development. Whereas in the 'market-pull' type of technologies, technology development and diffusion is greatly facilitated by the forces exerted by the marketing mechanism, in the 'technology-push' type (usually frontier-areas such as environment) of technologies, intervention of an agent or an extension agency often becomes necessary in order to promote and facilitate technological change. Further, in the case of societies, whose general level of literacy and technological orientation in law or where the old traditions and culture resist the introduction of new techniques and practices, the agent's role becomes even more crucial. In such situations, it may be necessary for the technology developer to arrange to set up 'demonstration' and pilot projects to convince the prospective users of the benefits of the new technology. Environmental science and technology development is indeed covered by the latter model.

Nevertheless, realizing the potential of science and technology for environmental protection and improvement and for promotion of sustainable development, tremendous efforts have been made in the region primarily induced by governments' efforts for its development, assimilation and adoption in the late seventies and early eighties. There are, however, several constraints. These arise mainly from low research and development expenditures, shortage of manpower and infrastructure, lack of focus on problems of relevance and poor adoption, assimilation and application. The succeeding paragraphs give some suggestions for promotion of a strategy for development of environmental technology.

Enhancing Research and Development Expenditures

Research and development constitutes the core of a nation's technological capability, more so in new sectors such as environment. If one analyses the total expenditures on research and development incurred in the countries, it is found that a relative proportion of these expenditures in most of the developed countries range between 2 and 3 per cent of GNP, while in the developing countries of ESCAP, it is in the range of 0.2 to 0.8 per cent of GNP. The component spent on the environment sector will, of course, be much less. In fact, in most cases the sums allocated to environmental research and development are not very significant. Further, it is spread too thinly over a number of projects to produce any tangible results. The situation is further complicated as the emphasis is placed more on the research component whereas more emphasis needs to be focussed on development aspects or demonstration models in this sector and also there is little concern for relevance, marketability and end-use of the results. In this context, following the experience of some countries, it may be useful to follow a rigorous selection procedure to determine the specific areas which need to be pursued for updating or producing new technologies or improving imported technologies. This should be in consonance with existing and potential capabilities and local technical manpower, must be relevant to needs and should be restricted to a few areas so as to produce tangible results. In addition, by formulating policies and plans for environmental technology development, the governments can create a favourable climate and stimulate and promote the advancement in the technological capability through a judicious mixture of policies instruments such as (a) fiscal policies (direct tax concessions, loans, grants, incentive etc.), (b) giving protection to indigenously developed technology by restricting imports, and (c) preference for indigenous technologies in public sector institutions etc.

Environmental Technology Forecasting and Assessment and Establishment of a Regional Environmental Technology Data Bank

It should be useful to carry out a survey of the environmental technologies being utilized in different countries in different sectors of environmental protection. Further, the assessment of the technological needs for dealing with newly emerging regional and global problems of environmental significance should be undertaken. In addition, there is a need to encourage technology assessment which deals with anticipation and evaluation of possible impacts of new technologies on various physical, economic, social and cultural factors and rendering of advise to the decision-makers as to whether the beneficial effects of new technology would outweigh its undesirable or uncertain results. Such a technological forecasting and assessment should assist the developing countries in having access to relevant and desirable technologies, when urgently needed.

In view of the acknowledged importance of environmental technology, both indigenously developed and imported, the establishment of a technology data bank in the region should be considered with a view to promote sharing of information and expertise in environmental technology. This data bank should collect information of 'what technologies are available,' 'where those technologies are available' and 'what has been the experience of various users'. In addition, exchange of information on 'adoption and assimilation of imported technologies' would also be very significant. Such a data bank could draw upon existing sources of technology information in the government, private sector, the UN systems, and other international agencies.

Sub-regional Coordination and Cooperation

Considering the vastness of the region, the national and international interest in the promotion of environmental science and technology and the needs for increasing cooperation, some regional organization such as ESCAP, could consider promoting an institutional arrangement in consonance with the suggestions made earlier for promoting coordination and cooperation on the sub-regional level in the development and transfer of technology. Such a mechanism may take fully into account the existing groups in the region at the sub-regional level, such as ASEAN Expert Group on Environment (AEGE), South Asia Cooperative Environmental Programme (SACEP), and the South Pacific Regional Environmental Programme (SPREP). To begin with, these sub-regional groupings could be utilized in promoting the regional science and technology data bank and in sub-regional coordination and cooperation. These groupings could even promote development and transfer of science and technology at a later stage.

Environmental Technology Diffusion

Out of the above components, the one relating to technology diffusion appears to be the most crucial in ensuring successful management of technological change. Some of the essential measures would include training at all levels, including those involved as 'agents of change' or extension educators, organization of administrative and legal machineries, finances and other inputs, measures aimed at the absorption and adaptation of technologies, organization of effective feed back mechanisms as amongst researchers, technology developers, users and beneficiaries, development of a cadre of competent research staff for science and technology, development and overcoming of resistance to change especially by those affected by the new technologies.

Environmental science and technology need not necessarily be very complex and out of bounds to the common man. In the majority of cases, it is simple and its usefulness is demonstrable. Encouraging public awareness and participation is an important pre-requisite for technology diffusion like promoting development, adoption and application of such environmental technologies. An enlightened public option can be an effective instrument for the development and propagation of environmental technology. With this in view, it may be useful to undertake programmes which would: (a) increase the peoples awareness of the usefulness of environmental technology, such as through mass media, television, films and radio programme, (b) demonstration of the usefulness of science and technology through exhibitions and fairs, (c) involving rural people and particularly youth and women in the organization of technology-based national competitions for demystifying the role of technology, and (d) creating an environment for innovation by introducing monetary and recognition incentives etc.

To sum up, environmental science and technology development would receive great encouragement through the creation of appropriate institutional, legal and fiscal measures, and promotion of science and technology information, education awareness, participation and diffusion. All these measures are generally intended to nurture and sustain human resource development appropriate for technological innovation and development. In this context, it may perhaps be relevant to mention that ESCAP had its main theme as 'Technology for Development' for its fortieth session in 1984. It is at present engaged in a comprehensive study on Technological Dimensions of Human Resource Development, which will be presented to the Commission at its forty-second session in 1986. Although these studies do not deal particularly with environmental technology, there are sections dealing with this subject. By and large, the future of environmental science and technology development in the region is rather bright, given the responses of the scientific and technological innovations in the countries in the face of tremendous resource constraints and growing problems of environmental degradation.

29

World Commission on Environment and Development

Jim MacNeill

All of us are concerned with advancing a better understanding of science among the broad mass of the people. It is our task to foster an appreciation of the scientific attitude and to loosen the bonds of superstition and ignorance. Like scientists elsewhere in the world, we are aware not only of the enormous benefits that scientists can provide to the peoples of the world, but also of the enormous responsibilities that the power of science imposes on you and on all of us. This is a subject to which I want to return.

India can be proud of her capabilities in science and technology that it has built nation-wide since Independence. It is world renowned. The Indian scientific community participates actively in the international community of science and has made significant contributions to economic and social development based on a remarkable degree of self-reliance.

I am particularly impressed by the recognition given to environmental issues by the scientific community in India. India has provided leadership on these issues from the very beginning of environmental action in the late sixties. The seminal role that the late Prime Minister, Mrs. Indira Gandhi, played in the global environment debate set an early example of deep concern for the precepts of sustainable development.

The Indian Government was among the first to establish an environmental agency. Mrs. Gandhi personally participated in the Stockholm Conference and the deep insights of her key-note address set the tone of the conference and greatly influenced the direction of subsequent international concern with environment. She was pereonally involved in launching the World Conservation Strategy and in a variety of environmental issues ranging from the pioneering efforts of Project Tiger, and the difficult decisions over Silent Valley, to the design of many industrial projects and the enactment of potentially far-reaching national legislation on air and water pollution. The world community is happy to note that the present government continues to play this leadership role.

When Mrs. Gandhi went to Stockholm in 1972 the world's environmental *problématique* appeared to be dominated by relatively simple questions—those of pollution, especially water pollution, and air pollution, and persistent pesticides. So prevalent was the impression that environment meant the self-created problems of the industrial rich that Mrs. Gandhi's remark, that the worst pollution was that of poverty, was seen as a stern and justified corrective which changed the course of the debate. The profound interconnections between environment and development were appreciated by only a few of those taking part in the international debate and Mrs. Gandhi's oft quoted phrase introduced that perception to a far wider audience.

India's contributions will be even more important in the future. Sadly, you are close witnesses to several of the new generation of environmental trends. They are scientifically more subtle than the earlier ones and economically, socially and politically, they are far more complex too. They are linked closely to development. In most countries they have been simply added on to the many conventional and mostly unresolved problems still in the pipeline of past development in the agricultural, forestry, industrial, settlement and other spheres. The way you cope with them will be watched by other countries, developed and developing, and your influence will be great.

While the late Mrs. Gandhi was among the first to realize it, today most of those engaged in the debate know that environment cannot be separated from development. The two are identical, linked by mutually re-inforcing bonds that drive each other either in an upward or a downward spiral. It is these links—economic, social and political—that make the present generation of issues so complex. And it is these links too that reveal the extreme limitations of our present institutions, national and international. Let me give you just three examples:

The first is the acidification of the environment from the cumulative effects of acid rain. The forests of Europe are dying with all of the consequences that implies. This winter, for example, Switzerland will begin the first evacuation of people from villages which are no longer protected from avalanches because the forests above them are dying. In Scandinavia and North America tens of thousands of lakes are without life. In Greece, the Acropolis and other marble monuments are turning to gypsum. And there is now evidence of acidification in many newly industrializing countries.

Here then is a regional-cum-global problem with dramatic economic and social dimensions and with a vast web of interconnections. Within a country, acid rain concerns ministries of agriculture, forestry, environment, building, interior, energy and transport. It concerns ministries of energy in neighbouring countries and their foreign ministries. It may involve transnational litigation. But at the core of it all, the science is still uncertain. Do we blame sulphur dioxide from fossil fuel burnt in power stations or nitrogen oxides or ozone from motor cars? Or both? And what is the mechanism? Is it dry deposition on the leaves, is it the liberation of aluminium in the soils? And is the acidification reversible naturally or are all Europe's forests doomed to die even if power stations were to clean up their emissions tomorrow? And what happens in tropical countries newly industrializing? Is India doomed not only to turn the Taj Mahal into gypsum but also to ring all its industrial centres with sterile acid soil too?

My second example is climatic change stemming in part from the dramatic rise in carbon dioxide concentrations in the atmosphere resulting from fossil fuel combustion. Recently, a meeting held under the auspices of the World Meteorological Organization at Villach in Austria concluded that a global temperature rise of around 1.5° to 3°C from the greenhouse effect was indeed highly probable, and that trace gases from aerosol propellants and methane might accelerate the rise so that effects will be apparent 30 to 40 years from now, around 2025.

With such change would come a sea level rise from thermal expansion of the oceans of 50 to 100 cms. This would result in serious permanent flooding of some low lying cities and coastal regions. Delta areas in countries like Bangladesh would be especially hard hit. The effects of such climatic changes on agriculture are uncertain—some countries would be better off, some worse. What is certain is that science is far from providing a solid basis for the evolution of a coherent policy for the planet, either with regard to forward planning to prepare for these effects, or with regard to delaying or stopping their onset by different energy policies.

My third example is the world's tragic response to desertification. A major conference was convened in 1977 under the auspices of the United Nations Environment Programme, and it adopted a Plan of Action to Control Desertification. But few of the governments which approved the plan provided the necessary funds. The plan would have provided five years of expenditure on anti-desertification programmes in Ethiopia by the time the recent famine struck. The cost was estimated at around $ 250 million. But no money was available for the prevention that these expenditures could have provided. Then the famine struck and when the cameras came the world community found twice that amount in one year to spend on emergency relief alone—just keeping people alive, still leaving the root causes unaddressed.

A four-year plan of desertification control has recently been proposed for the eight countries of the Sahel, not including Sudan and Ethiopia. It would combat soil erosion, stabilize sand dunes and reforest areas to provide fuel wood. If implemented, the cost will be $ 108 million for four years. US $ 108 million in pursuit of sustainable development. Contrast that with the cost of food aid for the inhabitants over the same four-year period, which is estimated at US $ 1,390 million.

When it is galvanized into action, or rather reaction, the world will not stand by and permit starvation. So it will find the money for emergency aid. But how much more sensible and economic it would be to anticipate and prevent these environmental disasters—rather than do as we do now, react after the event.

In the case of acid rain, the scientific uncertainties have given governments and their advisors excuses to delay action. In the case of climatic change, scientific uncertainty could mean that little or nothing will be done to avert what could be a global disaster. In the case of desertification, the lack of political will has already brought disaster. And there are as many other examples as there are development-linked environmental problems: rapid population growth, exploding urbanization, soil and forest destruction, spreading wastelands, chemicals, industrial safety—all of which you face in India—and many others.

It is clear that society must learn to anticipate more of the future stream of environment and development problems and act to reduce or prevent them—rather than simply react to them after the event, as we do now. But is also clear that most of our decision-making processes and institutional structures are ill-designed for that challenge.

It was this fact, I believe, perhaps more than anything else, that led the General Assembly of the United Nations to consider a special Commission to take a fresh look at the evolving situation. They sought a critical re-examination of the key issues from the perspective of the year 2000 and beyond and some proposals for effective action on them. This was to include institutional arrangements for more effective co-operation and action.

The resolution adopted by the UN General Assembly in 1983 called for its Secretary-General to choose the Chairman of the Commission and the Vice-Chairman. He selected Gro Harlem Brundtland, the former Prime Minister and present Leader of the Opposition of Norway; and Dr Mansour Khalid, the former Foreign Minister of the Sudan. They then selected the balance of the 22 Commissioners, who were chosen for their political eminence and leadership experience in science, industry, environment and development affairs. Fourteen of them are from the Third World, and the rest from the North, or, as we have to say sometimes, from the North-East and the North-West. Many of them are ministers, or ex-ministers, of finance, foreign affairs, energy, agriculture, environment and development. Some are distinguished in science, in industry and law. One of them is known to you—he is the President of the World Court of Justice and one of your most distinguished countrymen. The Commission established Panels and one of them, on

Food Security, is led by another of your distinguished countrymen: Dr M.S. Swaminathan, here with me on the platform.

Although the Commission is organizationally independent of the UN, it will submit its final report to the General Assembly of the UN in the fall of 1987. It is making a determined effort to ensure that its recommendations address the essential questions and are practical and implementable. Through Public Hearings which are held in conjunction with its regular meetings in all regions of the world, the Commission is listening to the views not only of distinguished scientists, scholars and officers of governments, but also of village headmen, community workers, and people from non-governmental organizations.

I cannot disguise the fact that one of the aims of the Commission's work is, if I may be brutal, to nail some lies—especially the lie that we can have development now and environment later. If decision-makers continue to think that development is for now, and environment is for when we can afford it, the world will remain on paths of unsustainable development, with accelerating environmental deterioration undermining the essential sources of development.

But let us ask who precisely are the decision-makers anyway? The phrase has become indispensable. We, all of us, feel that in any one situation society has arranged that someone or some defined group is responsible and takes the decisions.

There was a celebrated series of advertisements for a certain Swiss watch which we were asked to believe was just the thing for the wrist of those who make decisions—we see the coat cuff of an airline pilot, the hand of a sea captain on the engine room telegraph, the pen that will sign the big contract on the board room table, the surgeon pulling at the rubber gloves—but a moment's reflection shows that in real life decision-making is not that simple.

The room for individual discretion is very limited, even for the pilot of the passenger plane. The experience of his predecessors and his peers, the instructions of the manufacturers and the pressure from the insurers, all conspire to limit the area in which he can make decisions alone.

In the world of industry, the top executives usually make the big decisions. In the world of government, the decision-makers are traditionally ministers and their most senior officials. In both cases, they are surrounded by a greater or lesser number of advisors: economists, bankers, engineers, scientists. But on reflection, we see that their discretion too is limited by a sea of constraints, some arising from the experience of others, some from market forces, especially in the financial markets, some from public opinion and political pressures and some from less obvious things such as professional standards.

The engineering profession began to impose standards on its members well over a hundred years ago. Today, we take it for granted that a development project involving a dam cannot save money by cutting safety margins on the construction of the dam. Why not? Because the decision to use professional engineers is effectively the decision to observe their professional standards. Equally a decision to employ a doctor implies an engagement with the Hippocratic oath and a whole range of professional standards that go with the practice of qualified medicine.

But what about scientists? Are they different? Perhaps they are. They are uncertain, for example, whether they should be, as the saying goes, on tap or on top. Phrases like *pure* research, *basic* science suggest a rarefied activity, part of that mosaic of features that makes the image of the scientist. But however other-worldly and absent minded some scientists may be, they have, none the less, created our modern world. The modern understanding of disease and physiology is responsible for the reduced death rates that have permitted the population explosion.

It is chemistry and plant physiology that have given us the power to grow more food and kill off the competing pests and to create in Rachel Carson's memorable phrase a 'silent spring'. It is materials science that has given us the machines that remove a primeval forest in weeks or the power to divert a river from a course established even before man evolved. It is an understanding of thermodynamics that has given us the energy and muscle power to use fuel to fly, to tunnel, to level and to build. And it was physics that gave us nuclear power for peace or for destruction.

Depending on which way we look at it, we have a lot to blame, or thank, scientists for.

The future promises to be no less exciting or disturbing than the past. The impact of genetic engineering on mankind's capacity to manipulate the biosphere promises to become very great indeed. As the chemical industry expands and diversifies more than 2000 new chemicals are created each year to interact with the more than 80,000 already in the biosphere. The information revolution enormously extends the ability of mankind anywhere to deal as he wishes with his surroundings.

As the pace of scientific evolution quickens under the impact of goal setting by the state, as in the United States Strategic Defence Initiative or Japan's fifth generation computer project, so scientists will have to reckon more with society for their actions. It will not be a matter of being on tap, or on top, but a matter of assuming very diverse social responsibilities.

There are already manifest pressures in this direction. The process is regarded as having begun with that symbol of the rarefied, other-worldly scientist, Albert Einstein himself. It was his intervention with the government of the U.S.A. which harnessed science in the great and historic endeavour which led to the Atomic Age. We have become familiar with new bodies—Pugwash, the Union of Concerned Scientists, and recently, the Nobel Peace Prize has gone to physicians who banded together to raise public awareness of the nuclear winter. It is not just in the area of physics and weapons that scientists have shown a willingness to anticipate social responsibility. In the case of research in DNA they themselves established the regime of differing degrees of containment for laboratories engaged in the area.

I believe that scientists, as a body of professionals, should go further. Their discoveries will have increasing impact on the environmental basis of development, for good or ill or, very likely, both together. As society becomes increasingly aware of development under avoidable pressure from a deteriorating environment, public opinion will increasingly discern scientists themselves as sharing in a responsibility to anticipate the effects of their discoveries.

The World Commission on Environment and Development sees the need to promote a deep change of attitude to the environment on the part of decision makers and their advisors. Instead of reacting after the event and seeking to cure environmental ills, it wants to see 'anticipate and prevent' become the watchword of those with influence. No one is better placed than the scientific community in the realm of anticipation. You can see better than most what scientific discoveries can bring. And as doctors seek through the Hippocratic oath to anticipate the effects of a treatment on their patients and to balance the positive and negative side effects, so could you, as scientists, seek to anticipate the effects of the research in which you are engaged and balance the positive and negative effects of it on environment and development.

A code of ethics for environment and development is more than an interesting idea for discussion. Some other groups have taken halting steps in that same direction. The latest is the World Federation of Engineering Organizations and its simple, one page draft was debated in this city three months ago in November.

Such an initiative will not be easy for you, it is never easy for anyone. The question is a particular challenge for the elder statesmen of science. They are the ones who find themselves on research councils which determine the pattern of public spending. They are the advisers to industry and they strongly influence what the young are taught.

Can you lead your profession, not just in India but worldwide, to take on its environmental responsibilities? Can you take the place that your creative powers entitle you to take in the college of decision makers and protect the future from the environmental degradation that undermines the basis for essential development?

Why should I raise this question for the first time with scientists in India? Why not in Washington or Tokyo or Paris? The answer is easy—India is uniquely placed as a country that knows, from the heart, the whole range of environment and development problems from the basic ones of extreme poverty to those presented by advanced technology, and by technology still in the future. The leadership of Indian scientists could be uniquely influential in the world as a whole.

You also have a tradition to keep up—a tradition of activism on environment and development issues which was begun at the top by Mrs. Gandhi but is striking roots everywhere with an active non-governmental movement. The poor people who began the Chipko movement have been an inspiration to poor people around the world. And the admirable 'Citizens Report on the State of the Indian Environment' is being seriously looked at as a model that other advanced countries might do well to copy. So, there is every reason for the scientific community to take its place in India's tradition and help make environmentally sustainable development the essence of a scientist's sense of responsibility.

30

The Status of Environment and Development of Environmental Science and Technology in China

Lu Jiaxi and Liu Jingyi

Environmental problems have emerged mainly as a result of social activities of mankind. Following the industrialization of human societies, the soaring increase of population and the accelerated exploitation of natural resources, harmful or even poisonous matter has entered into the natural environment at an unprecedented rate; as a consequence, environmental problems have become more and more acute and required more and more immediate attention. As a matter of fact, they have already become one of the major problems facing mankind as a whole. In order to more rationally utilize natural resources and assure sustained development of national economy, China has come to realize that environmental protection is one of her basic and long-term problems on a nation-wide scale.

Characteristics of Environmental Problems in China

Our country is a developing socialistic country with widely different geological and ecological environments in different regions. Notwithstanding the fact that our country has a vast territory as well as a rather rich storage of natural resources, the huge population of slightly over one billion renders our holdings of resources per capita very low, holdings of biological resources in particular. The holdings per capita of farmland, grassland, forests, land used for agriculture and afforestation, and runoff are all much below the world average figures. With a very long history of human civilization and a rather early exploitation of natural resources, our social background, geological exploitation, economic structure, and development of modern science and technology differ from other countries as well. Hence, our environmental problems have their specific characteristics. At present, damage to ecosystems and environmental pollution have led to grave concern over the seriousness of the situation.

Serious damage to natural ecosystems is becoming a very challenging environmental problem in our country. Its main manifestation lies in the damage to vegetation, soil erosion, soil salinization, desertification, and abnormal climatic changes, thus resulting in decreasing productivity of natural ecosystems (such as farmland, grassland, forests, rivers, lakes, seas, and ground water).

Air pollution by airborne particulates and SO_2 (SO_x) and nitrogen oxides (NO_x) has been found in large and medium sized cities to quite a serious extent. In coal producing and consuming areas of northern regions, it is even more serious in water. Acid rain and its ensuing acidification of the environment is becoming more and more challenging in some cities, particularly so in the southwestern regions.

Water pollution is rather serious in several regions. The annual discharge of waste water is estimated to be 32 billion tons for the whole country, most of it being discharged without any treatment at all into rivers, lakes, and seas. About 90 per cent of water in the vicinity has been polluted to various extents. Rivers in some cities have become very polluted, leading to very serious problems in the economic development of these cities on account of their limited water resources. More than 180 large and medium sized cities in the whole country are in urgent need of supplying at least 10 million tons of water per day. The pollution of ground water in many cities has also become serious year by year, and water quality has become increasingly worse. Due to excessive exploitation of ground water, there are regional funnels in some northern cities, leading to surface subsidence and thus aggravating the shortage of water resources.

Most of urban domestic garbage and industrial solid wastes have piled up uncovered without undergoing any treatment at all. In 1980, the amount of industrial wastes piled up over the past few years had reached 5.3 billion tons, occupying about 40,000 ha of land. This is in urgent need of immediate attention.

Urban environmental noise pollution is also becoming another serious problem. 84 per cent of urban traffic noise has exceeded national tolerance standards; indeed, 40 per cent of urban residents have lived and are still living in conditions where the noise level exceeds these tolerance limits.

Agricultural environmental pollution has spread throughout the country. In 1980, farmland affected by urban waste gases, water and solid wastes and farmland polluted in the small towns have reached intolerably high figures of 4 million and 1.7 million ha respectively. Again, pollution caused by irresponsible use of high-toxicity pesticides is becoming relatively common; the area of farmland polluted by pesticides is estimated to be over 13 million ha, amounting to about 15 per cent of the farmland of our country.

This environmental pollution has undoubtedly brought about tremendous damages to the economic development and the public health of our country. Our government has therefore taken measures to minimize the harmful aftereffects of these pollution problems, and both efficient environmental protection and rational ecological balance have been adopted as a basic national policy to be upheld for years to come. As a matter of fact, we have finally come to realize that the improvement of living environments must be one of the most basic requirements in the enhancement of public living standards.

Policy Considerations of Our Environmental Protection Before the End of This Century

In the year 2000, the total output of our agricultural and industrial production will be double compared with the year 1980, in order to improve the living standards of the people to a decent level. For the environmental aspects, we shall strive to realize that the main environmental pollution problems in our country will be more or less satisfactorily solved, and the natural ecosystems will basically reach a stage of benign operating cycles; the production and living environments will be clean and healthy; on the whole, the environmental status of the whole country will harmonize itself with the development of the national economy and the improvement of material and cultural life for the people. Before 1990, as far as economic construction is concerned, we shall have harnessed some of our troublesome rivers and developed some such regions correspondingly, and we shall be able to effectively protect and reasonably utilize our own natural resources (water, land, minerals, and forests), as well as to devote major efforts to growing grasses and trees in order to gradually change the severe situation of land erosion and control the trend of desertification in certain regions. We shall strengthen the monitoring and control of air pollution, water pollution, land pollution, and noise pollution, and reinforce the protection and prevention of natural disasters, thus improving the environment of key cities and tourist areas and gradually creating a better living and working environment.

In the ensuing ten years, we shall rely more on technological progress for rational exploitation and multipurposed utilization of natural resources. It is expected that there will be a period in which our environmental science and technology will be very much developed and appropriate technologies will gradually be adopted for the elimination of 'three wastes'. The concept of systems engineering will become the guiding principle in the control of natural resources as well as in regional prevention and control. Along with that, the pollution of particulates and SO_2 will be put under control, while emphasis will be focussed on the removal of nitrogen oxides (NO_x), the smoke purification technologies with lower energy and water consumption as well as the technologies for desulphurization and denitrification with regard to water pollution control. Attention will also be focussed on the control of eutrophication and the prevention and control of ground water pollution.

It is expected that our agricultural production well be rapidly developed, ecological studies of the countryside will be very much intensified, the public consciousness for the need of a healthy ecological environment will generally be enhanced. It is expected that in the year 2000, the area of afforestation will be expanded to about 190 million ha, and the covering rate of forests will be raised to over 20 per cent.

We believe that so long as we accept and persist in environmental protection and ecological balance as our basic national policy, and take appropriate measures including policies, technologies, economies, and legislations, our status of environment in the year 2000 will probably meet the strenuous requirements of the 'redoubling' and 'a decent level of living standards'.

Development of Environmental Science and Technology in China

Environmental science and technology in China has developed very rapidly, though it has not emerged as early as in the developed countries. Studies on environmental science have so far dealt with environmental chemistry, environmental geology, environmental physics, environmental biology, environmental engineering, environmental toxicology, environmental economy, environmental management, and so on. The development environmental science and technology in China may be summarized as follows:

1) From 1949 to 1973 (i.e., pre-National Conference Period after the founding of the People's Republic)

Since the founding of the People's Republic in 1949, a series of measures have been taken for the improvement of environmental conditions and agricultural ecology. In urban areas, from the point of view of accelerating economic development and protecting public health, the old cities have undergone transformations to a certain extent. During the early fifties, large industrialization projects were undertaken on the basis of rational localization and yet sufficiently uniform regional distribution, and construction was carried out on a large scale. As a consequence, the impact on coastal cities has been much reduced. In the countryside, farmland construction was developed to a great extent. Some large water conservation projects were well carried out so that rivers such as Huai River, Hai River and Yellow River were brought under control, resulting in effective improvements in agricultural production. From the fifties to the sixties, in connection with some rather troublesome environmental problems in the country, such as natural disasters, deforestation, water and soil erosion, pasture degeneration, desertification, salinization, mud-rock flow, locust and other pests, and some endemic diseases, a number of research institutions were set up. In some large industries, measures were taken for the treatment of waste water, noise control, dust removal, and multi-purpose utilization of the 'three wastes'. In 1972, an extensive investigation organized by the Chinese Academy of Sciences on the pollution problems in Guanting Reservoir, the main source of water supply for the metropolitan Beijing, was carried out, and a series of control measures were proposed and organized on this basis.

2) *From 1973 to 1983*

In 1973, the First National Environmental Protection Conference was organized by the State Council. The basic principle of 'overall planning, rational distribution, multi-purpose utilization, transforming harm into benefit, relying on the masses and enlisting everybody's effort to protect the environment and bring happiness to the people', as well as concrete measures for pollution control, were proposed. Since then the environmental protection work in China has made conspicuous progress. The Environmental Protection Law was promulgated in 1979. Later laws, regulations, and standards specifications were formulated one after another. During this period many research institutes were organized to join in relevant research programmes in our Academy and also in a number of governmental industrial ministries as well as provinces and large cities. Since then, environmental science has made very good progress, benefitting people in a number of ways. The First National Development Plan for environmental science and technology in China was drawn up in 1977 and the national scientific and technological research plan for environmental protection was formulated in 1979. Social science research on environmental problems was also started at this time.

Important achievements in environmental science and technology have been made during this past decade.

1) Investigations on polluting sources and studies on environmental quality assessments has provided a scientific basis for the formulation of environmental protection plans and policies. Since the 1973 investigation of water pollution in Guanting Reservoir, steps taken in water resources protection in Baiyangdian and Ji Canal and investigation on oil pollution, and control studies in coastal regions such as northern Bohai Sea and Yellow Sea have been organized on a large scale. For the urban and industrial areas, environmental quality assessment was carried out on the western outskirts of Beijing and Shenyang (in northeast China). Some large projects, such as the industrial bases for energy resources in Shanxi Province and the Beijing-Tianjin-Tangshan Region, as well as work on environmental quality assessment were also organized so as to study the feasibility for the establishments of proposed industrialization bases and adjust the environmental impacts by economic development.

2) Pollution control techniques for industrial pollution sources have been studied. In connection with the control of phenols, cyanides, mercury, chro-

mium, and arsenic, the abatement technique is used mainly for the treatment of waste water from the electroplating industries, oil refineries, textile printing and dyeing industries, paper mills, and so on; new techniques have been worked out, such as membrane technology, high magnetic separation, anaerobic degradation, ozone oxidation, activated carbon adsorption and biological treatment. Cycling of waste water in oxidation pond and land treatment, as well as water self-purification capacity, have been studied. So far there are 41 municipal sewage treatment installations in China with a capacity of more than 1.2 million tons of sewage water per day. Among them, the sewage treatment installation in Tianjin is the largest put up so far, with a daily treatment capacity of 260,000 tons, covering practically one-fourth of the urban area in that metropolitan city. There are 38 oxidation ponds with a daily treatment capacity of 1.16 million tons. Oxidation pond in Yaer Lake, developed by our Academy with a daily treatment capacity of 80,000 tons, is capable of purifying pesticide waste water by bacteria-algae symbiosis. The organics in the sewage are degraded by aerobic becteria into simple N, P-containing matter and CO_2 available for algae growth and reproduction, and the oxygen released by algae through photosynthesis is in turn utilized by these bacteria for further degradation of organic matter. The cost for the treatment is rather low. I have personally witnessed the course of development and successful use of this symbiotic bacteria-algae treatment for waste water from a petroleum refinery and petrochemical industry complex in Beijing area from the initial stage of water ill-smelling, high in COD value (i.e., Chemical Oxygen Demand), and certainly not suitable for drinking purpose to a final stage of water good-tasting, constantly low in COD, and possibly good enough for drinking purpose.

For air pollution control, improvements have been made to a certain extent, such as static dust remover and bag dust remover, besides boiler-reforming adopted for enhancing the efficiency of dust removal. The static dust remover designed for it has a removal capacity as high as 125 million cu m/h. High temperature filtering materials and large bag-dust removers have already come into common use. As coal is by far our major energy resource, extensive studies on control technologies of SO_2 and acid rain have already begun. Some results have been obtained in coal washing and briquetting process, fluidized-bed combustion, and gasification and desulphurization of flue gases. There are more than 2,000 fluidized-bed boilers with an evaporation capacity of more than 10,000 tons/h. During this period of time, attention was also focussed on environmental pollution caused by solid wastes. Multi-purpose utilization techniques on furnace slag, burgee and gangue have been studied. Materials recovered can be used for building, road paving and improvement of soil quality.

3) There have been rapid advancements in the development of environmental monitoring techniques, as well as in analytical equipment design and production. The analysis of environmental pollutants has undergone develop-

ment from intermittent chemical analysis to continuous automatic sampling and instrumental analysis. Our Academy, in collaboration with other research institutions, has worked out more than 200 analytical methods for at least 50 pollutants. Automatic air pollution monitoring and water quality monitoring instruments have been developed; even remote sensing techniques have been in use in some large sized cities and regions.

An environmental protection industry in China has been started, including nearly 1,000 environmental protection equipment manufacturers with an annual output value as high as one billion yuans. Quite a number of pollution control equipments and home-made monitoring instruments are now being supplied in China.

4) Research in environmental science has also made sufficiently good progress. With regard to the overall environmental control, the relationships between environmental protection, food resources, and population growth have been studied, as well as geochemical circulation of P, N, Hg, Se and other relevant elements. In regional environmental studies, our Academy has also carried out:

a) environmental study on the Beijing-Tianjin-Bohai Bay region;

b) large-scale pollution control of Xiang River, the largest tributary of Yantze River; and

c) studies on pollution control of mercury in the second Songhua River (a large river in northeast China).

The atmospheric studies in Beijing area include physical and chemical studies made on a 320 metre meteorological tower built by our Academy, atmospheric diffusion modelling, chemico-physical characterization of airborne particulates, transformation of SO_2, etc. A large amount of environmental information in this area has already been obtained. Some achievements have been obtained such as the transport and transformation mechanism of heavy metals, BHC (benzene hexachloride) pesticides, polyaromatic hydrocarbons and various undesirable petroleum products in the environment, atmospheric diffusion models in boundary layers, oxygen balance models in river water system and studies on the mechanism of biological control. Investigations on natural resources in different ecological systems have been carried out in forests, grasslands, wastelands, plains, and water bodies. Some natural conservation areas have been established on the basis of studies made on the development and utilization of these areas. Apart from the large scale epidemiological survey, toxicity and health effects have been studied so far with regard to pollutions caused by some chemical contaminants and the abnormal abundances of some undesirable chemical elements such as Se, I, F, etc. in certain regions of our country.

At present, the environmental science and technology in China has progressed from the study of simple pollution treatments to regional pollution prevention and control, from industrial pollution prevention to ecological and natural resources protection, from pure science and technology studies to relevant social science studies. Nowadays, environmental research has become much wider in scope. A comprehensive study of environmental science and technology and their interaction with national economy and other social factors has been organized so as to optimize their environmental, social, and economical effects, with cost-benefit analysis for the improvement of natural environment and development of national economy.

3) *After 1983*—the beginning of a new phase in national environmental control

In the Second National Environmental Protection conference held at the end of 1984, environmental protection has received nation-wide recognition as a basic national policy, that is, economic construction, and urban, rural and environmental protection have been taken into overall consideration together with the national planning. We have already reached a stage that we may say the development of environmental science and technology in China has entered a new phase. Obviously, the important features of environmental science in its new phase are the incorporation of ecological viewpoint, multi-disciplinary and multi-levelled study of regional environmental problems, and emphasis on integration of social, economical, and environmental effects. Recently priority in the environmental protection work has been given to the urban ecology studies in China. Urban environmental management and control are undertaken with the following goals in mind:

1) Urban area taken as the key area in our environmental protection work;

2) Rational adjustment of urban industrial structure and construction planning;

3) Multi-purpose control of urban air pollution;

4) Multi-purpose control and treatment of pollution in urban water sources and systems;

5) Harmless urban garbage disposal;

6) Multi-measured control of urban noises;

7) Organized planting of trees and grasses on a large scale;

8) Proper investments for multi-purpose treatment of urban environmental problems;

9) Full policy support for multi-purpose control of urban environment.

At present, a concrete development project for environmental science and technology is being formulated. No doubt a large amount of concrete work awaits to be done for creating a clean, healthy, and peaceful environmental condition in China. I am certain that Chinese scientists will only be too glad to devote themselves as well to the improvement of global environmental conditions (environmental conditions in the Asian region in particular).

31

The Global Economic-Environment Interdependence

Asit K. Biswas

Environmental issues caught the interest and the imagination of people in North America in the mid-sixties, when the number of citizens' groups and non-governmental organizations proliferated. They tried to focus the attention of the public and the politicians to environmental problems by publishing environmental abuses and degradations, some real and critical, others not so.

With increasing public interest, the news media started to provide a wider coverage of environmental problem. *Time* magazine initiated a new section entitled *Environment*. Similarly articles on environmental issues in the *New York Times* skyrocketed from about 150 in 1960 to around 1700 by 1970, but have declined significantly since that time (Biswas and Biswas, 1982).

In many ways, similar developments cannot be noted in a few select developing countries like India and China. Interest in environmental issues in both these countries have increased in the recent years, and during my frequent visits to both these countries, it is quite evident that media coverage of environmental issues have increased significantly commensurately. It is now difficult to visit either of these two countries at present without being interviewed by the media, whereas similar interest a decade ago was very minimal.

There is another similarity between the developments in North America in the mid-sixties and India at present. While real environmental experts are playing an important part in shaping national environmental policies, equally there are many pseudo-environmental experts lending their 'instant' expertise to provide gloom and doom statements. In the West, publications like *The Limits to Growth* and *A Blueprint for Survival*, both published in 1972, were readable, attracted wide readership, and heightened short-term public interests by prophesies of gloom and doom. The former report tried for the first time to analyse the complex interrelationships between population, resources, environment and development by computer modelling most simplistically. In so doing, and by ringing the doomsday bell most vigorously, it provided a bandwagon for parties who were already more than convinced that mankind was headed straight for disaster, unless some of the growth-oriented policies were forsaken (Biswas, 1982, 1979).

The latter polemic was written in Britain and was signed by many respected scientists. As Lord Ashby of Brandon (1978) observed on this report: "On practically every page there were assertions repugnant to the rational reader: plunges into naive fallacies; innuendo; patently incorrect assertions; and statements unsupported by published and accepted evidence". Reviewing some of the environmental developments of this period, one can say that the remarkable aspect about such apocalyptic visions was not that they were so wrong, but that they were written with great force and passion by some distinguished scientists, whose main field of expertise was not in the environment but in other areas. Just because one is an eminent neurosurgeon or a nuclear physicist does not necessarily mean that the person is automatically an international expert on the environment well beyond their expertise, even though the media and many other people who should have known better implicitly made this erroneous assumption. Environment has many facets and it is impossible to be an expert in them all.

Regrettably, a similar analogous situation can be witnessed in India at present. Recently some publications on the Indian environmental issues have received considerable publicity, both nationally and internationally. Full of factual errors, devoid of rigorous scientific analyses, liberally sprinkled with dogmas and half-truths, and pandering to vested interests, such publications will create significantly more problems for the nation than they will resolve. Anyone that advocates selected and simple solutions to complex environmental problems facing India should remember that for each complex problem there may be a simple solution, which may appear to be economic and simple to implement but generally totally wrong.

The Global Interdependence

During the past three decades, differences between expectations of development patterns and the developments that have actually taken place have been remarkable. Our perception of development has also changed. Gone are the heady days when politicians, academics and planners had a ready recipe for development and how to achieve it promptly.

We are more cautious now. For example, during the Third General Conference of the United Nations Industrial Development Organization in New Delhi in 1980, many governments expressed the opinion that the "two United

Nations Development Decades had failed in their objectives". It is now generally conceded that the development process is not as simple and straightforward as earlier anticipated and that there is no foolproof way of hurrying up the process.

On the positive side, the successes and failures of development in various developing countries have enhanced our understanding of the complexities of the different development processes. It is now better recognized that development is a multidimensional concept which encompasses not only economic and social activities but also those related to population, use of natural resources and their resulting impacts on the environment.

While there has been some understanding in the past of the interrelationships between people-resources-environment-development, the approaches adopted to solve problems had been basically sectoral. Admittedly the interrelationships concept is not new, but the need for rapid development and technological advancement has meant that very often whatever knowledge of interrelationships was available tended to be disregarded. Fortunately this situation appears to be changing in many developing countries at present.

We know now that attempts to solve seemingly environmental problems like desertification and the loss of productive soil or deforestation, emphasis should be placed not only on such physical factors like climate, soil type, modes of cultivation or land-use patterns, but also on many other diverse factors like demographic trends, types of technology used, levels and distribution of income among the population, consumption patterns, cultural habits, and educational levels of the inhabitants. Without such an integrated approach, action taken to solve a specific problem could give rise to several other unintended side effects, the sum total of which could even be worse than the problem to be resolved.

Among the many critical global problems we face at present are fundamental issues of war and peace, providing basic needs to an ever-increasing world population; the problem of debt crises in the Third World, especially in Brazil, Mexico, Argentina and Venezuela; the impact of the debts on the commercial banks in developed countries; a high interest rate; consistent low prices of raw materials on which the export income of many developing countries depend; high unemployment in both developed and developing countries; signs of protectionism in international trade and commerce everywhere; the neglect of the agricultural sector in most developing countries, on which the majority of their people depend for their livelihood; and the increasing gap in income and privileges between the rich and the poor world-wide, both inter-country and intra-country. One may legitimately ask why such broad issues are important to environmentalists, and why they should be concerned with them. My answer is very simple. In the final analysis, all these broader issues will have a direct and substantial impact on the environment.

Of the many complex issues interrelated with environment, consider population.

There is no doubt that rapid population growth has serious environmental as well as developmental implications. While it may not have the dramatic and immediate impact of a debt crisis or energy crisis, its impact on the world on a long-term basis is equally real, and probably more important. The 1985 estimate of the world population was 4.84 billion; it is not only the number but the rate at which it has increased during the past two centuries which is important. The world population doubled from about 300 million in the year 1 to 600 million in more than 1500 years. During the period 1750 to the early twentieth century, the rate of population growth was about 0.5 per cent per year, which was unprecedented before this period. Interestingly, during this period, the growth rate was higher in today's developed countries than in other areas. By 1950, the growth rate had increased to 1 per cent per year and then to an even higher rate of 2 per cent. The world population steadily increased from 2.5 billion in 1950 to 4.8 billion in 1984 (Fig. 1).

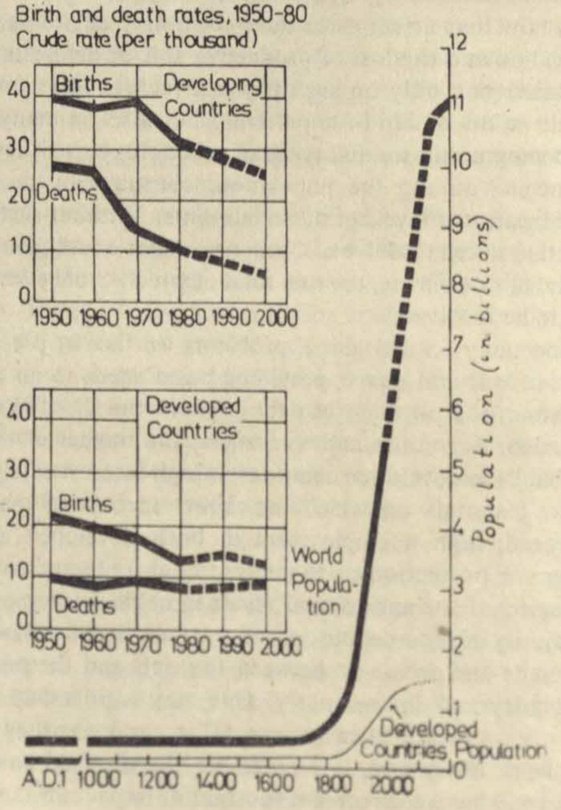


Fig. 1. World population.

Since 1950, population growth has been primarily concentrated in developing countries, and these growth rates were historically unprecedented. The growth rate peaked at 2.4 per cent per year in the sixties and has dropped to about 2 per cent at present.

According to the latest World Bank projections, the global population could reach 9.8 billion by 2050 and stabilize at more than 11 billion around 2150. The population in developing countries is projected to increase from 3.6 billion today to 8.4 billion by 2050. In contrast, the population in developed countries during the same period is projected to increase from 1.2 billion to 1.4 billion. Table 1 shows the situation for the 10 most populous developing countries for the period 1985–2050.

If we look even further than 2050—to the time when the world population stabilizes around 2150—India would continue to remain the most populous nation at 1.7 billion. Nigeria and Bangladesh will have a population of 620 million and 450 million respectively. Viewed differently, a country like Bangladesh, with a per capita GNP of US $ 140 in 1982, and having an area of 144,000 sq km (approximately equivalent to that of the state of Wisconsin in the U.S.A.), will have a population that is significantly higher than that of the entire U.S.A.

One aspect of population growth has been rapid urbanization. Latin America is the most urbanized of developing country regions since about 65 per cent of its inhabitants live in urban areas, a level reached by developed countries in 1950. Africa and Asia, however, are still predominantly rural, with only 25 per cent of their population urbanized, which is somewhat similar to the level reached by developed countries before 1900.

The cities in developing countries are now growing at about twice the rate of the total population. Between 1950 and 1980, the urban population of all developing countries, excluding China, increased by 585 million. In 1950, no city from any developing country had a population of more than 10 million. By the year 2000, 21 of the 25 largest cities of the world will be from developing countries, and the population of all these 25 cities will exceed 11 million. London, which was the second largest city in 1950, will not even be within the top twenty-five (Table 2). India will have four cities within the top twenty-five cities: Calcutta, Bombay, Delhi and Madras—in that order.

There is of course no one-to-one interrelationship between population and environment or population and development. For example, even though the world population has tripled since 1950, real income has increased by around six times, and life expectancies of people have increased significantly as well. The life expectancy and primary school enrolment rates in poorer developing countries like India, Pakistan, Bangladesh, Ethiopia or Sudan are comparable or even better than the situation existing in developed countries in 1900. Present GNP per capita of these developing countries are comparable to that of Japan in 1900.

TABLE 2

Major urban agglomerations in 1950, 1975 and 2000

1950	
New York/NE New Jersey	12.2
London	10.4
1975	
New York/NE New Jersey	19.8
Tokyo/Yokohoma	17.7
Mexico City	11.9
Shanghai	11.6
Los Angeles/Long Beach	10.8
Sao Paulo	10.8
2000 (Projected)	
Mexico city	26.3
Sao Paulo	24.0
Tokyo/Yokohoma	17.1
Calcutta	16.6
Greater Bombay	16.0
New York/NE New Jersey	15.5
Seoul	13.5
Shanghai	13.5
Delhi	13.3
Rio de Janeiro	13.3
Greater Buenos Aires	13.2
Cairo/Giza/Imbaba	13.2
Jakarta	12.8
Baghdad	12.7
Tehran	12.7

Furthermore, during the past three decades, many developing countries managed to increase their per capita average income in spite of the rapid growth in population. For example, the average income in India grew from $ 170 to $ 260 (1980 dollars) between 1955 and 1980, an increase of 1.7 per cent per year. In contrast, in the U.S.A. with a much lower population base and lower rate of population growth, the average income increased by 2 per cent per year during the same period. However, in absolute terms, the average income in the U.S.A. increased from $ 7,030 to $ 11,560 in constant 1980 dollars. This means the income gap of $ 6,850 in 1955 between average annual American and Indian incomes increased to $ 11,300 by 1980. The average American annual income increased from 41 times the Indian income in 1955 to 44 times the corresponding income by 1980. In other words, even if the rate of increase of the two annual incomes were not all that different, in absolute terms the difference not only persisted but also increased significantly.

There are many popular myths about the interrelationship between population, resources, environment and development. First, the issue of how crowded the Earth is. If we resettled all the 4.8 billion people in a country like Burma, whose area is 677,000 sq km, a family of four would have 570 sq m, which is a typical single-family, one-storey home in North America with a front and backyard.

Second, there appears to be very little or no relationship between level of income and population density. For example, the U.S.A. and Ethiopia had a somewhat similar number of people per sq km in mid-1982, 24.7 and 26.9 respectively. Yet, per capita GNP was $ 13,160 in the U.S.A. and only $ 140 in Ethiopia. Hongkong and Singapore had 5,200 and 2,500 people per sq km, and yet their GNP per capita were $ 5,340 and $ 5,910 respectively. Similarly prosperous Japan has 31.8 persons per sq km and GNP per capita of $ 10,080 compared to developing India with 21.8 persons per sq km and GNP per capita of only $ 260.

One can argue that it is not land that is important but arable land since non-cultivable land may be of little economic significance. By this yardstick, however, Japan compares even more favourably with India, and Ethiopia has more arable land per capita than Singapore or Hongkong. Similarly sparsely populated kingdoms like Saudi Arabia. Kuwait or Qatar have limited arable land but some of the highest per capita incomes in the world.

In spite of the above comments, the fact remains that rapid population growth is slowing the development process in developing countries, and it is the poor who pay a heavy price for it by a lower quality of life than otherwise possible due to the lost opportunity to improve their status. Similarly population growth often contributes to or accelerates environmental problems, and accordingly information on the size, structure, age distribution and rate of growth is essential for any evaluation of environmental impacts and changes.

The implications of population growth on the environment can be traced through a vast multitude of pathways, the most important one of which is the production and distribution of food. During the period 1961 to 1976, developing countries increased food production at a faster rate than developed countries, but because of rapid population growth, their per capita food production grew at a much slower pace. In Africa, per capita food production during 1961-65 to 1980 actually declined by 1 per cent a year. The situation was better in Asia. For example, if we consider India, its average annual growth rate for population since 1950 has been 2.1 per cent whereas the corresponding growth rate for food production has been 2.7 per cent (Fig. 2). However, food production per capita has fluctuated widely during this period depending on the monsoon. In a bad year, when the harvest was poor and food prices were high, many small farmers and landless labourers went hungry (Biswas, 1984).

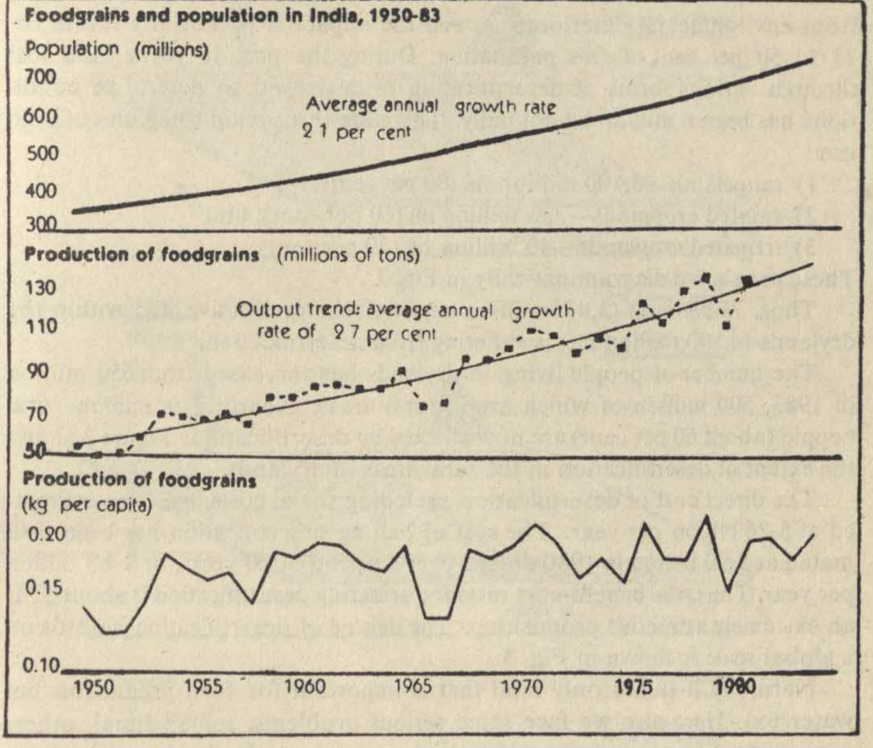


Fig. 2. Comparison between foodgrain production and population in India, 1950-1983.

Increase in population also has a direct impact on land holding patterns. In India, the number of rural households increased by 66 per cent between 1953-54 and 1971-72, and during the same time the amount of cultivated area increased by 2 per cent. This resulted in an increase of marginal land holdings of less than one acre (0.41 ha) from 15.4 million to 35.6 million, and the average farm size fell from 0.27 acre (0.11 ha) to 0.14 acre (0.06 ha). Similarly in Bangladesh, the average land-person ratio declined from 0.4 acre (0.16 ha) in 1950-61 to 0.29 acre (0.12 ha) in 1979-80.

From a people-resources-environment-development-interrelationship viewpoint, it is not only the extent of cultivable land that is important but also the quality and technology used for farming.

On the first point, quality of land, the latest information available is not exactly something to cheer. Desertification, which is defined as loss of land productivity due to various reasons like deforestation, overgrazing, overcultivation, waterlogging, salinity development, etc. threatens 35 per cent of the Earth's land surface and 20 per cent of its population. Nearly 75 per cent of the threatened area and 60 per cent of the affected area are already suffering from environmental deterioration, and the impact is particularly severe for 25 to 50 per cent of this population. During the past 10 years, land lost through various forms of desertification or destroyed to desert-like conditions has been 6 million ha annually. There are three main categories of land use:

1) rangelands—3,100 million ha (80 per cent);
2) rainfed croplands—335 million ha (60 per cent); and
3) irrigated croplands—40 million ha (30 per cent).

These are shown diagrammatically in Fig. 3.

Thus, 75 per cent (3,475 million ha) of all the productive land within the drylands (4,500 million ha) is suffering from desertification.

The number of people living in drylands has increased from 650 million in 1983, 500 million of which are in rural areas. Nearly 280 million rural people (about 60 per cent) are now affected by desertification. Figure 2 shows the extent of desertification in the rural areas of drylands.

The direct cost of desertification, excluding social costs, has been estimated at $ 26 billion per year. The cost of halting desertification has been estimated at $ 90 billion in 1980 dollars over a period of 20 years, or $ 4.5 billion per year. Thus, the benefit-cost ratio for arresting desertification is about 5 : 1, an extremely attractive proposition. The degree of desertification hazards on a global scale is shown in Fig. 3.

Naturally it is not only land that is important for food production but water too. Here also we face some serious problems, some natural, others man-made. Shortage of water is a major constraint to further irrigation development in countries like Sudan and Egypt and in parts of Brazil, China and India.

There is no doubt that irrigated areas will continue to increase in the foreseeable future. In 1980, the total amount of irrigated area in developing countries was of the order of 160 million ha, more than half of which was in China and India. As more and more desirable sites are developed for agricultural production and the development potential of some major irrigating countries like Egypt reaches a plateau, the future growth rate of irrigated areas is likely to be lower than that witnessed in the seventies. With real investment costs reaching $ 2,000 to more than $ 10,000 per ha, funds will not be easily available in the future for massive developments. Thus the maximum rate of expansion for irrigated areas that can be realistically expected by the year 2000 will probably be of the order of 1.7 per cent per annum, a rate that is slightly lower than in the recent past (Biswas, 1986).

While shortage of water may be a constraint to irrigation development in

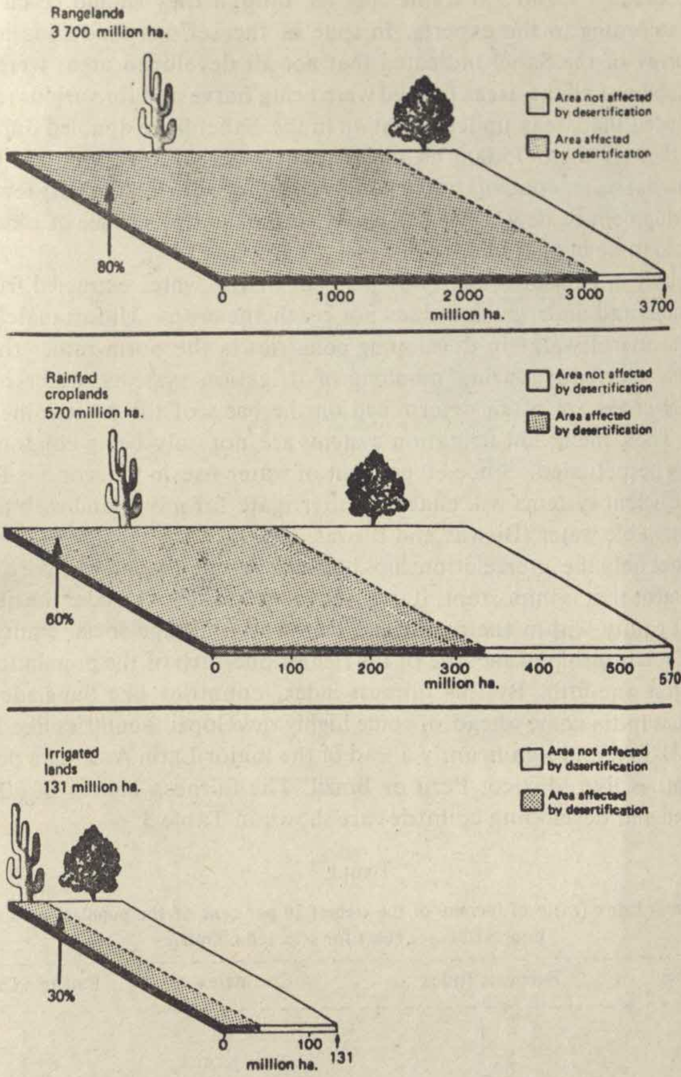


Fig. 3. Global extent of lands at least moderately desertified by land use.

many parts of the world, it must be said that an equally important, if not greater factor is poor irrigation management. An analysis of irrigated agriculture in the Sahel by the Club du Sahel pointed out that the expected high yields and double annual cropping was not occurring. Yields of rice, the main crop farmed under irrigation, at the Office du Niger have varied in recent years between 1.7 and 2.6 tonnes per ha, though they should reach 5 to 6 tonnes according to the experts. In spite of the serious food situation, the 1979 survey of the Sahel indicated that not all developed areas were being farmed and not all the areas farmed were being harvested for various reasons. It concluded that areas under irrigation in the Sahel have doubled during the period 1960–1979 (to 75,000 ha under total water control and 155,000 ha under partial water control) but generally speaking, during the past few years, the development of new areas has barely surpassed the surface of older ones which had to be abandoned.

Similarly in Pakistan, nearly 67 per cent of the water extracted from the River Indus and underground does not reach the crops. Unfortunately such inefficient use of water in developing countries is the norm rather than the exception. Currently during planning of irrigation systems, water requirements for crops are often determined on the basis of the present inefficient system. Thus, inefficient irrigation systems are not only being condoned but are being perpetuated. Since 80 per cent of water use in the world is for irrigation, efficient systems will enable us to irrigate far more land with the presently available water (Biswas and Biswas, 1985).

It is not only the interrelationships between people-resources-environment-development that is important, it is equally important to consider the question of social equity within the countries. One way to judge social equity is in terms of relationship of income of the richest one-fifth of the population with the poorest one-fifth. By this fairness index, countries like Bangladesh, Sri Lanka and India come ahead of some highly developed countries like France and the U.S.A. and significantly ahead of the major Latin American developing countries like Mexico, Peru or Brazil. The fairness indices of 20 select developed and developing countries are shown in Table 3.

TABLE 3

Fairness index (ratio of income of the richest 20 per cent of the population to the poorest 20 per cent) for selected countries

Countries	Fairness Index	Countries	Fairness Index
Finland	4 : 1	Indonesia	7 : 1
Denmark	5 : 1	South Korea	8 : 1
Japan	5 : 1	Tanzania	8 : 1
Netherlands	5 : 1	France	9 : 1
Sweden	5 : 1	United States	10 : 1
United Kingdom	5 : 1	Malaysia	16 : 1
Bangladesh	6 : 1	Venezuela	18 : 1
West Germany	6 : 1	Mexico	20 : 1
Sri Lanka	6 : 1	Peru	32 : 1
India	7 : 1	Brazil	33 : 1

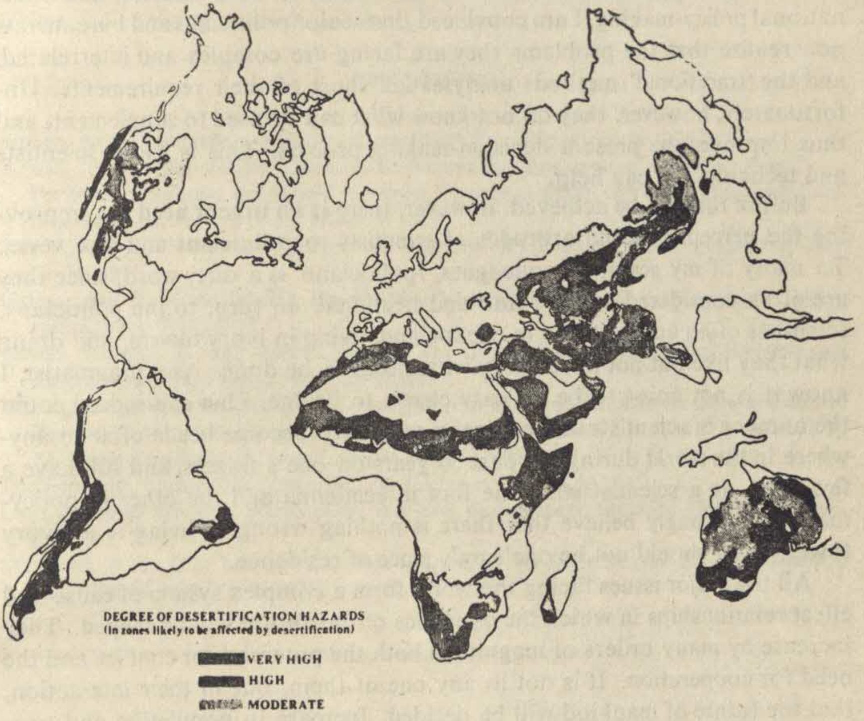

DEGREE OF DESERTIFICATION HAZARDS
(In zones likely to be affected by desertification)
VERY HIGH
HIGH
MODERATE

Fig. 4. Degree of desertification in the world.

Where does environment come into all this? My point is we are now living in a complex and interrelated world. The interrelationships are not only between people-resources-environment-development at both country and international levels but that dynamic interrelationships also exist between countries. Currently no major policy decision can be taken either at the country level that will not affect some people adversely or at the international level that will not have negative impacts on some countries. For example, we hear much about the rapid increase in oil prices since 1973, and the adverse impact this has had on the development plans of the Third World countries. Unfortunately, however, decreases in oil prices have not been welcomed by all developing countries. For example, for every dollar fall in the oil prices, the balance of payment of a country like Brazil has improved by $ 250 million and that of Mexico has declined by $ 560 million. Similarly any major national policy will have its own sets of beneficiaries and those who will pay the cost. Political decision-making in the final analysis depends not only on the monetary cost of implementing a policy but also on the nature and extent of the beneficiaries of that specific policy.

Having been involved for more than a decade in both national and international policy-making, I am convinced that senior politicians and bureaucrats now realize that the problems they are facing are complex and interrelated, and the 'traditional' methods analyses fall short of their requirements. Unfortunately, however, they do not know what can be used to supplement, and thus improve, the present decision-making process. This is where scientists and technologists can help.

Before this can be achieved, however, there is an urgent need for improving the perceptions and attitudes of scientists to politicians and vice versa. To many of my scientific colleagues, 'politicians' is a dirty word, since they are often considered to be dumb and irrational. In turn, to the politicians, scientists often appear to be in cuckooland, living in ivory towers, and doing what they like but not necessarily what needs to be done. As a pragmatist, I know it is not going to be an easy chasm to bridge. One can indeed count the number of scientists and engineers who have become heads of state anywhere in the world during the past 50 years on one's fingers, and still have a few left! As a scientist with one foot in academia and the other in policy-making, I strongly believe that there is nothing wrong in living in an ivory tower, but it should not be one's only place of residence.

All the major issues facing the world form a complex system of cause and effect relationships in which the dynamics of our future will be shaped. They increase by many orders of magnitude both the potential for conflict and the need for cooperation. It is not in any one of them, but in their interaction, that the future of mankind will be decided. Increase in population and provision of basic human necessities to each individual mean more food, energy, and raw materials; intensifying the supply of food means more land, water, energy, and fertilizers; the energy crisis and higher oil prices mean less energy available to increase food production and to alleviate fertilizer shortages; and the common denominator in virtually all responses to these problems must include more capital, more technology, and more cooperation. It is here that these concerns inevitably merge with the important issues of war and peace, monetary and trade relations. Each affects and is affected by the others. This system of relationships is global in scale. That is not to say that all global problems can be met with global solutions; there are few global solutions. But they can be only be understood and dealt with in a global framework, within which there can be a wide variety of national and regional responses.

What is necessary is the realization that the ultimate self-interest of all nations is inevitably merged in the inescapable web of inter-dependencies. An integrated cooperative approach is needed for managing the interacting relationships between resources (their development, distribution and use), and the minimal needs for sustaining decent standards of human life and protecting the environment on which that life depends. These interlocking subjects must be foremost on the world's agenda for consideration and action. Only through the understanding of these intricate interrelationships will it be possible to solve the mammoth problems facing us.

REFERENCES

Biswas, Asit K. Irrigation in Africa, *Land Use Policy*, 3(4), October 1986.

Biswas, Asit K. "Population-Resources-Environment-Development: A Systems View," Presidential Address, 4th World Congress, International Society for Ecological Modelling, Tsukuba, Japan, 18 p., 1984.

Biswas, Asit K. Global Future Studies: A Review of the Past Decade, *Mazingira*, 6(1): 68–75, 1982.

Biswas, Asit K. World Modes, Resources and the Environment, *Environmental Conservation*, 6 (1): 3–10, 1979.

Biswas, Margaret R. and Asit K. Biswas. The Global Environment: Past, Present and Future, *Resources Policy*, 11(1): 25–42, 1985.

Biswas, Margaret R. and Asit K. Biswas. Environment and Sustainable Development: A Review of the Past Decade, *Third World Quarterly*, 4(3): 479–491; Reprinted in *Philippine Geographical Journal*, 26 (4): 160–173, 1982.

The Ecologist, Blueprint for Survival, *The Ecologist*, 2(1): 1–43, 1972.

Lord Ashby of Brandon, *Reconciling Man with Environment*, Stanford University Press, Stanford, 1978.

Meadows, D.H., D.L. Meadows, J. Randers and W.W. Behrens. *The Limits to Growth*, Basic Books, New York, 1972.

VIII

CONCLUDING SESSION

32

Report by the President

T.N. Khoshoo

Honourable Prime Minister, may I join the Vice Chancellor in welcoming you to this Concluding Function of the 73rd Session of the Indian Science Congress Association. Without sounding clanish, you being a technocrat, the members of the Congress take you as one of them. The Science Congress is today 73 years young. I say young purposely, because over 60 per cent of our total membership of 10,000, is in the late teens or early twenties. ISCA is not a highbrow Academy, it is, in every sense, a grass-root science organization. Traditionally, ISCA has been a platform for the first exposure of young scientists to the scientific community at large.

During its 73 years, it has had the good fortune of having stalwarts as its General and Sectional Presidents, starting with Sir Asutosh Mukerjee in 1914.

Initially the emphasis of ISCA was to announce discoveries at the annual meetings. However, with many professional specialist societies coming into being, by and large, this has shifted to specialist societies. With this, the Science Congress took to discussion of national issues that transcend narrow boundaries of disciplines; and the concept of Focal Theme was born about ten years ago. Now, our major objective is to bring science and public-interest together, or, how Pandit Jawaharlal Nehru put beautifully, is to make our countrymen 'science-minded' and scientists 'nation-minded'. In this regard, I see a remarkable parallelism between Science Congress and BAAS and AAAS, who are our counterparts with memberships running in thousands like ours.

After the Addresses of the General and Sectional Presidents are delivered, we divide ourselves into 13 sections, two Committees and one Forum which encompass all basic sciences, engineering, and socio-economics. In each group research papers are discussed, Symposia are held and special lectures delivered. There are also public lectures. From the deliberations of each group, recommendations emerge which are discussed in our General Body. These are refined and put up to the Department of Science and Technology (DST), which is our Nodal Department for such action as the government may deem fit. There is an Inter-departmental Task Force under the Secretary, DST, which oversees the implementational aspects.

Each section also recommends young scientists, for ISCA Awards based on the work that is presented in the Congress.

This years focal theme was 'Science and Technology in Environmental Management'. It was based on the central premise that environment is 'the sum total of all conditions and influences that affect the development and life of all organisms' including the human being. Thus, living systems are central to the whole environment and life and scientists should have a major and a deciding role.

Twelve priority areas emerged which are discussed in my address. In each case, the state-of-art was surveyed, and future lines of action, research and development needs and policy decisions to be taken were identified. The priority areas are:

— Population stabilization
— Integrated land use planning
— Healthy cropland and grasslands
— Woodland and revegetation
— Conservation of biological diversity
— Control of pollution in water and air
— Development of non-polluting renewable energy systems
— Recycling of wastes and residues
— Ecologically compatible human settlements and slum improvement
— Environmental education and awareness
— Updating environmental law and
— New dimension to National Security.

Some specific observations are:

1) The plans for environmental management need integration from the very inception in all the developmental activities of all sectorial authorities from a Ministry down to a *Panchayat*. Implicit in the statement is that:

> A Department of Environment has a 'Watch Dog' Role and clubbing it with any other Department will be ultimately counter productive.

2) Programmes on environmental amelioration can succeed only when participation of the public is secured and ensured, and the public at large develops a stake. Implicit in this statement is that a mass education and awareness programme on environment needs to be undertaken. The idea is to sensitise individuals. This is very important because what is a society or a government—it is an extension of an individual.

3) A strong science and technology base is needed for environmental research and development, education and training and demonstration and extension. This is an essential prerequisite for any meaningful progress in this area. An equally important area of work is the social cost-benefit: in other words, at whose cost and to whose benefit.

4) Mechanisms need to be strengthened for ensuring:

a) Corrective, curative or restorative action for the past environmental damage. An example of such action is Mission on Ganga.

b) Pre-emptive action needs to be taken regarding the environmental damage expected from the future developmental activities and thereby insulating the country from further damage. An outstanding example of this is the stoppage of the Silent Valley Hydroelectric Project in favour of the role that this area has as a repository of biological diversity.

While a list of recommendations will be sent to DST, may I highlight a few items:

1) For development to be sustainable, the environmental dimension must be fully incorporated into the nation's planning process. In fact, this has to be a permanent objective.

Because of the multi-disciplinary, trans-sectoral and inter-governmental nature of environmental management, policy makers at the national and state level now need an advisory body which can assist them in developing policies on pressing national environmental issues. This body could be modelled after our own Scientific Advisory Committee to the Cabinet, or the Council on Environmental Quality which advises the President of the U.S.A. Such a body could immediately start policy research.

2) Development of a National Conservation Strategy. Such a document should cover those issues which directly or indirectly affect environmental quality, such as population policies, the patterns of land use, the management of natural and human resources and also the inter-relationship between population, resources and environment. It must take account of issues such as water resources development, mining, recycling and re-use management of hazardous substances. It should also identify the respective roles that governments, private sector and non-governmental organisations have to play in achieving the goals of sustainable development.

Logically, the National Conservation Strategy should lead (preferably in time for the next five year plan) to the formulation of a National Policy for Sustainable Development.

3) Integration of the Environment into sectoral policies. This requires the appointment, as recommended in the Tiwari Committee report, of competent environmental advisors at the ministerial, state, sectoral and other appropriate levels.

4) Establishment of environmental management institutions. Such institutions, possibly networked by a central institute for environmental manage-

ment studies, would serve the research, training and consultancy needs of the various sectoral, central, state and non-governmental bodies in the field of environment.

5) Himalaya. As a pilot, world-class institution for developing the concepts of environmental management, the government should expedite the establishment of the Indira Gandhi Institute for Himalayan Environment and Development.

6) Biosphere Reserves. One of our distinguished biologists and conservationists, Prof. Dillon Dipley while delivering the Ramdeo Memorial Lecture this year at the Congress said with despair that during the past 50 years he has been visiting India and has seen unprecedented deterioration in biological wealth of the country particularly in NE & SW India which are areas of largest biological diversity.

Management of biological diversity is becoming a major global enterprise with considerable economic benefits. In contrast to National Parks and Sanctuaries, a lot of effort by very competent people has gone in the preparation of plans for Biosphere Reserves. We know precisely what is to be conserved and how.

In sum and substance, the message of the Seventy–third Session of ISCA is loud and clear. It is 'Put Science and Technology to use in the Management of the Country's Environment' for sustaining development in the country.

Honourable Prime Minister, you are leading the nation to a better future. Let me assure you, that the membership of ISCA is with you in this great venture that promises to be full of excitement in doing new things. We have hope and expectations of you, and I am sure, you too have hopes and expectations of us. On behalf of ISCA, Hon. Prime Minister, I wish you all success. I suggest you use ISCA.

In order to translate socio-economic goals into realities by application of science and technology, we need management skills as against the mundane administration skills. The two are different. Our administration was evolved by the British to consolidate the British Raj in India, and not take leaps forward for economic and social development. The most urgent need of the hour is to manage these areas and not just administer them.

In 1984, I accepted the honour of presiding over the seventy–third session with a deep sense of humility and of pride as it is the highest non-governmental honour that scientists of the country can bestow on a fellow scientist. I realize the tremendous responsibility associated with this office. I don't know if I have come up to the expectations of my fellow scientists, but let me tell you, friends, the year 1985—the year of my Presidency—has been an exciting year for me personally, full of challenges which had so much to offer me by way of new knowledge and new experience. I am deeply grateful to you, the members of the Congress, for affording me this rare opportunity.

33

Indian Science Must be Equal to the Best

Rajiv Gandhi

The Indian scientific tradition dates back to ancient times. There was a period when India was sought out as a centre of learning, a centre of science and technology. Indian scientists made an appreciable contribution towards the development of science in those early days. Without going into the long list of specific details, let me quote from a seventh century Syrian bishop, Severes Sebokht. Referring to Indian scientists, he says, 'There are subtle discoveries in astronomy, discoveries that are more ingenious than those of the Greeks and the Babylonians. Their valuable methods of calculation and their computing surpasses description.' That perhaps describes what Indian science was like a couple of thousand years ago.

Unfortunately, we went through a period of subjugation which saw the destruction of this scientific and technological tradition. It saw India reduced from a much sought-after destination for knowledge and riches to an underdeveloped and developing country.

Today the challenge that our scientists and technologists face is greater than the challenge that our scientists faced a couple of thousands of years ago. The challenge now is not just to catch up with, to equal, what is going on in the rest of the world. But the challenge is to surpass and once more give the lead that we used to have some thousands of years ago. Our scientists must concentrate on what is most meaningful for a country like India. And in today's circumstances that means in the rural areas, the agricultural sector, and the various sectors that support our agricultural and rural industry. Our scientists have considerable achievements to their credit during these past years. They have put India in a strong, self-reliant position, not just in agriculture but also in certain strategic and sensitive areas where it was difficult for us to import technology. Where there have been a real challenges, where the chips have been down, our scientists have risen to the occasion and have shown the world that they are second to none when it comes to capability, competence and achievement.

Thrust Areas

The question today is how are we going to spread this out to other areas. While we have been tremendously successful in certain specific areas, we have been wobbling around and not really achieving anything in many other areas. The question is not just of scientists. The scientists are there, the brains are there. The real question which we are facing in science, in technology, in research, and generally across the board is that of management. How are we going to handle our scientific management. This perhaps is the root of getting more output from our scientists.

Pandit Nehru, addressing the Indian Science Congress in 1963, had said, "Our laboratories have done good work and yet I have a feeling that all is not quite well with these labs". Perhaps I could repeat that today. Questions of seniority, questions of a bureaucracy coming into scientific management, of mediocrity creeping in at the higher administrative level and many other such questions have to be answered. They cannot be answered by us, they must be answered by you scientists. The only real way to get our best scientists operational in their fields is to refuse to accept mediocrity at any level. And this is the real challenge that our scientists must tackle on their own.

We have seen by experience, as I have just mentioned, that where we have set out a particular task or challenge, our scientists and technocrats have responded and delivered. Perhaps it was seeing a goal in front of them, or just the fact of having either to deliver or to have to wind up a particular scheme, or the threat of a close down of a particular research which worked. But the fact is that it has worked and we have now tried to follow this in other areas as well.

We have already identified certain thrust areas where we will concentrate in such a manner as we have done with our space research, our food production, our nuclear research, and some other areas. We would like now to broaden that thrust into areas which are critical to us like energy, oilseeds, and certain high technology areas where we need the technology which we are not able to get from other countries. What is required is not just for government to sponsor scientific research. Government sponsorship will perforce be limited to certain areas and also in quantum to certain limits. We have traditionally spent too little on scientific research. We have to increase this. But we must get a proportionate increase also from industry and various other sectors.

We have also to try and see that our research is once more brought into the centres of learning. Our universities are not being used for research as they should be. Our industries are not going to our universities and wanting research done, wanting improvements. This, somehow, must happen. We have already given instructions to the public sector units that they must go to universities, they must go to our laboratories and ask for results. I hope that this will begin happening. Similarly, we have asked our defence industries to try and reach out to as many institutions as possible and not to concentrate in their own few establishments. Again this will give a new life, a new thrust, to scientific research right across the country.

Must Jump to the Front

What is still lacking is the demand to improve on what we already have imported. If we get a technology, whether it is a production technology, or a particular technology for defence, or any other frontline technology, we must not be satisfied with just getting it and sitting on it for 20 or 30 years and suddenly saying "My God, we have got left behind!" That should only be a stepping stone, a starting point, from which our scientists must take up the challenge and catch up and get ahead of other countries in basic research, in basic understanding.

Today we are in a position from which we can take this lead in many areas. For much too long have we been playing this game of chasing other people's research. It is not good enough. It is not going to work any longer. It has served its purpose during this phase of our development, but that phase is over. Now we must target for frontline research, not try and do what others have already done. We must learn from what we have done, and we must take that jump and get to the front, to the cutting edge of research, the cutting edge of technology. I know that the capability is there in our scientists, but it requires just that little bit more thrust.

I think we are amongst the top countries in the numbers of papers that our scientists produce. But how many of these papers are quoted by other scientists? How many are referred to by others? Do we ever hear of these papers some years later or do they just disappear? This is a question that we must face and we must see that what we produce is really top-grade front-line stuff. We have the capability. We have demonstrated it, our scientists have demonstrated it. We must bring them out and let them flower in a similar manner in every field. Of course our funds are limited and it will mean certain restrictions, but what is required is that whatever investment we make is utilized, used in the most effective manner that it can be. We are today looking towards developing various technologies, whether it is in energy, whether it is in certain areas of food production, oilseeds, whether it is in certain specific defence areas. What we are looking for is to use the most modern technology for the benefit of the poorest and the most depressed in our country.

'Appropriate' Technology Concept

There have been theories of appropriate technology, but 'appropriate' to me means second-rate, being deliberately kept backward so that we keep playing a game of catch-up. We are fed up of playing the game of catch-up. We want now to get on the front-line. We should not be satisfied with second-rate technologies, second-rate development. We must go to the front areas.

Our farmers have demonstrated that they are capable of using front-line technologies. That is why we are self-sufficient in food today. And if our farmers, who perhaps could have been considered one of the most backward groups as far as scientific education is concerned, are capable of this jump, then almost every section of our society is capable of absorbing technology. We have to see that we create the correct educational environment for them to be able to absorb these.

Scientific research is not just a question of producing a few hand-picked scientists who can reach pinnacles of achievement. It must be supported by a very broad base of people who have scientific learning, from which we can draw and reach out to the best people that are available. This we have not been able to do. We have got pillars which reach out to great heights, but they remain pillars. We have to turn them into pyramids.

When Panditji talked about the scientific temper, it was not limited to developing a handful of scientists. It was a scientific temper that had to permeate down to the average Indian, whether he was living in a town or whether he was living in the remotest village. This perhaps is another major challenge that we must face. We have to develop our education system so that this scientific temper permeates down to the average person. It is only when that happens that more people will be drawn into the scientific field, that more people will get the opportunity which will enable us to tap the best brains that there are, which today are not accessible to us.

Ecological Challenge

You have been discussing and talking about ecological problems. Perhaps this is again one of the biggest challenges that we in India face today, that the world faces today. As science develops, it is no more a question of how fast, of how good our research is. It is more a question of whether man himself as a human being will be able to advance adequately enough to cope with this knowledge that he is gaining. Will he be able to handle this knowledge or will science and technology take over and lead us down the path which ends in some sort of holocaust—either a traumatic nuclear holocaust or an environmental collapse? And the challenge is in linking the development of the human being with the development of science and technology.

In India, traditionally we have concentrated on the development of the soul and the mind, the spiritual development of the human being. Today the challenge that we are faced with is of combining this traditional Indian heritage with modern material development. It would not be satisfactory for us to achieve only material, technological development. We have to match it with the development of the human being, with the inner spiritual development of every individual in India. We are trying to marry the two to get the best from both. We feel that without this linkage we would not be getting true development of the human being in India.

With our traditions, we should be able to find some options which have been rather elusive. Our task in India is to end poverty. The challenge to our scientists is: How can modern, scientific and technological knowledge be brought to bear on the task of removing poverty? How we can bring our rural, more backward areas not just a step behind the other countries but equal to the most developed countries? That challenge has been in front of our scientists, in specific fields. They have shown that they can do it. I look forward to our scientists accepting that challenge and bringing India ahead of the most developed countries in certain fields and gradually in all the fields.

34

Recommendations on the Focal Theme

RECOMMENDATIONS FROM THE GENERAL PRESIDENT'S ADDRESS

1) *Advisory Body on Environment*: For development to be sustainable, the environmental dimension must be fully incorporated into the nation's planning process. In fact, *this has to be a permanent objective.*

Due to the multi-disciplinary, trans-sectoral and inter-governmental nature of environmental management, policy makers at the national and state level now need an advisory body which can assist them in developing policies on pressing national environmental issues. This body could be modelled after our own Scientific Advisory Committee to the Cabinet, or the Council on Environmental Quality which advises the President of the U.S.A. Such a body could immediately start policy research.

2) *Development of a National Conservation Strategy:* Such a document should cover those issues which directly or indirectly affect environmental quality, such as population policies, the patterns of land use, the management of natural and human resources and also the inter-relationship between population, resources and environment. It must take account of issues such as water resources development, mining, recycling and re-use, and management of hazardous substances. It should also identify the respective roles that government, private sector and non-governmental organisations have to play in achieving the goals of sustainable development.

Logically, the National Conservation Strategy should lead (preferably in time for the next five year plan) to the formulation of a National Policy for Sustainable Development.

3) *Integration of the Environment into Sectoral Policies:* This requires the appointment, as recommended in the Tiwari Committee Report, of competent environmental advisors at the ministerial, state, sectoral and other appropriate levels.

4) *Establishment of Environmental Management Institutions:* Such institutions, possibly networked by a central institute for environmental management studies, would serve the research, training and consultancy needs of the various sectoral, central, state and non-governmental bodies in the field of environment.

5) *The Himalayas:* As a pilot world-class institution for developing the concepts of environmental management, the government should expedite the establishment of the Indira Gandhi Institute for Himalayan Environment and Development.

6) *Biosphere Reserves:* Management of biological diversity is becoming a major global enterprise with considerable economic benefits. In contrast to National Parks and Sanctuaries, a lot of effort by very competent people has gone in the preparation of plans for Biosphere Reserves. We precisely know what is to be conserved and how.

RECOMMENDATIONS FROM PLENARY SESSIONS AND SECTIONAL DELIBERATIONS

I: Summary

1) Environmental Data Bases and Modelling

— Air and water pollution including toxic chemicals
— Water: Use and efficiency
— Watershed management (including hydrological systems)
— Biological populations
— Agro-eco-systems

2) Conservation and Development of Resources

— Conservation of plants, animals and micro-organisms in terrestrial and aquatic including marine areas on an ecosystem basis (Biosphere Reserves)
— Species for Multi-purpose use
— Ethnobiology and dissemination of traditional knowledge
— Efficient use of fuel resources
— Preservation of historical sites

3) Ecosystem Restoration

— Mined areas
— Mangroves
— Watersheds
— Fragile ecosystems
— Resource recovery and re-use

4) Research Needs

— Atmospheric chemistry and physics (including use of lasers)

- Remote sensing
- Integrated pest management
- Organic farming: No till and minimum till agriculture.

5) *Regulation and Implementation*

- Updating environmental laws pertaining to:
- Water and air pollution (including standards for ambient quality)
- Mining
- Pollution control at source
- Urban zoning (including siting of industry, urban development)
- Statutory requirement for environmental assessment
- Safe disposal of hazardous wastes.

6) *Environmental Education*

- Formal education at primary, secondary, tertiary and university (post-graduate research) levels, including of professional and technical, personnel.
- Non-formal education for non-student youth, rural and urban people, administrators and decision makers.

RECOMMENDATIONS FOR DIFFERENT SECTIONS/COMMITTEES/ FORUMS

Section: Mathematics

1) A national data bank should be set up for maintaining:

a) Inventory of storage of toxic chemicals in the country. The quality to be stored at various installations should be determined on the basis of the extent of toxicity of the materials.

b) Ambient air quality data

c) Emission data (both stack as well as fugitive)

d) Meteorological data.

2) a) A national ambient air quality monitoring network should be set up to assess the degradation of the environment due to rapid industrialization.

b) Existing ambient air quality standards should be reviewed and revised as appropriate in relation to health and welfare of the people.

c) Appropriate air quality models should be used in assessing the environmental impact on the optimal industrial development of the country.

3) Monitoring of stack emissions from vital installations should be made obligatory. Immediate control measures should be developed and implemented for automotive related emissions to minimize the degradation of the ambient air quality and the environment.

4) Facilities for measurement of meteorological parameters on real time basis should be developed at vital installations where emergency response models should also be provided.

5) Mathematical model studies on environmental management should be supported.

Section: Statistics

1) Applications of stochastic models for forecasting and simulation of hydrological systems of river basins affected by industrialization, urbanization, population explosion etc. should be developed.

2) Stochastic model studies on Population ecology in areas like fish harvesting, biological control, epidemiology, forestry and air pollution (including forecasting and spread of toxic chemicals) need to be supported.

3) Official statistical system should be required for collection and dissemination of realistic statistics on different aspects of environmental management.

Section: Physics

Optical methods of monitoring Environment and pollutants using lasers should be emphasized.

Section: Chemistry

Greater opportunities should be provided for appreciation and awareness programmes on environmental chemistry, particularly on general hygiene and environmental pollution. Teaching and Research on Environmental Chemistry should be supported.

Section: Geology and Geography

1) Appropriate legislation should be enacted for safeguarding against environmental hazards created by mining and mineral industries. Provisions should also be made for adequate incentives for industries adopting suitable measures to maintain healthy environment in and around mining centres.

2) A compulsory cess should be levied on the mining industry for protection of environment and an authority be set up to utilize the funds for environmental protection.

3) Studies should be taken up on large mining belts employing, among other methods, latest techniques of remote sensing for locating mineral deposits and involving geo-scientists.

4) Legislation is necessary to protect mangrove-swamp ecology and stability of beaches as well as other types of imbalances caused by large scale developmental activities. Preservation of environment should form an integral part of planning and development of any large scale developmental projects that tend to disturb man-environment balances.

5) For protection of quality of urban environment, green belts, fruit belts in particular should be developed.

Section: Botany

1) Identification of suitable plant species for fuel and fodder in different

agro-climatic zones of the country with a view to providing basic human needs without disturbing the natural environment and also for reclamation of waste lands should be given priority.

2) For this selected species on a large scale should be made available.

3) Indiscriminate destruction of mangroves providing habitat of innumerable biota should be stopped and protection of seashores be assured.

Section: Zoology, Entomology and Fisheries

1) Proper exploitation and utilization of animal resources towards the welfare of mankind should be made.

2) Conservation of germ plasm of domesticated plant and animal species, including flora and fauna in general should be assured.

3) Recycling of organic waste as potential resources for energy and other industrial raw materials should be explored.

Section: Anthropology and Archaeology

1) Ancient relics like monuments and other architectural tombs are not only to be protected but sufficient care should be taken by the town planners to preserve their architectural beauty, particularly important for new cities developing around the old ones.

2) Proper steps are to be taken to record and preserve them, develop modern scientific basis and to encourage their use by majority of the people.

3) Popular audio-visual mass media are to be utilized to develop people's awareness about our rich cultural heritage to bring about what is known as composite approach to preserve cultural heritage. The sites where fossils (hominid as well as primate) have been excavated may be preserved.

4) Steps are to be taken also to renovate the damaged monuments without affecting the originality.

Section: Medical and Veterinary Sciences

1) For proper disposal and recycling of garbage, and sanitary land filling adequate steps should be taken up.

2) More attention should be paid to the development of high altitude physiology and aviation medicine.

3) Aerobiological checking must be done in all hospitals for pathogenic organisms.

Section: Agricultural Sciences

1) Soil, water and other input management should be geared to achieve high productivity, stability, sustainability and equitability, in agricultural production.

2) Overexploitation of soil should be avoided; also recuperation of soil health through practices such as crop rotation, inter-cropping, mixed cropping

wherever feasible should be followed. Supplementation of inorganic fertilizers with organic manures, bio-fertilizers, which are renewable and can be recycled, should receive greater and more concerted attention in soil management practices.

3) Research on high doses of fertilizers and irrigation water necessary for high production with a view to increasing the efficiency of these inputs should be strengthened.

Section: Physiology

1) A national institute should be established to undertake research and offer advanced training in the field of under-water physiology and medicine.

2) Infrastructural facilities and technology should be created for undertaking research on physiological and biomedical problems during future space exploration.

3) Facilities should be provided in the Universities and concerned National Institutions to set up standards for safe exposure to pollutants and environmental extremities and to develop personal protective equipment.

Section: Psychology and Educational Sciences

1) Education should help develop the inner potentialities of individuals. This in turn will help improve the non-physical environment.

2) Environmental dimensions of educational programmes should be incorporated in formal as well as in non-formal sectors.

3) For effective resource management, home management needs to be given due importance in educational programmes.

4) Environmental psychological studies/researches should be encouraged to help planners/administrators and other agencies to strike a balance between natural environment and human activity.

Section: Engineering Sciences

1) Environmental Impact Assessment of all the future and ongoing development projects need to be taken up.

2) A strong information base needs to be proposed at the block level to help in proper propagation of alternative source of power and cheap devices for irrigation.

3) Economical design of farm implements, and facilities for grain storage may be provided to cut down losses and prevent ecological damage.

4) To provide large scale employment to rural low cost technologies in sanitation, housing, transport including bullock cart, communication including radio, television should be suitably encouraged.

5) Industrial Safety Designs may be prepared and provided to the industries for execution.

6) Organization for recycling and re-use may be set up for disposal of water and its recycling.

7) Voluntary agencies may be fully associated with massive field programmes of environmental protection.

8) The quality of life may be improved by creation of plans for aesthetic and pleasing landscapes.

9) Industries should also fund instrumentation and environmental process control.

10) Data banks may be established and strengthened for environmental protection control.

Committee: Science and Economic Development

Conservation is essential to the survival of man. Therefore, time has come to enhance ecological research and evaluation in all our economic developmental activities. Science can contribute invaluably to national development by providing the much needed ecological view point which is inter-disciplinary and systematic in nature.

Committee: Science and Its Social Relations

1) For the spread of science and scientific attitude in the younger generation (the citizens of the twenty-first Century) on a massive scale activities of Vigyan Parishads (and similar organizations) operating in regional languages should be encouraged by the Government by giving suitable *ad hoc* and adequate recurring grants to each State Parishad.

2) The government should immediately declare moratorium on forest cutting and tree felling by contractors especially in the Himalayan belt and in the hinter lands of big dams.

3) A time targetted project should be taken up to prepare and publish a series of bi-lingual and multi-lingual dictionaries in *Devanagari* script covering all our regional languages.

Forum: Home Science and Nutrition

1) Review of designs in biogas and smokeless *chullah* technologies and training programmes for personnel at different level be undertaken.

2) Research in traditional health practices and folk remedies be undertaken.

3) Youth in educational institutions as well as non-school going children must be actively involved in developmental programmes especially in literacy, nutritional education and infant and preschool care.

PLENARY SESSIONS

A. Seventy-second Session: High Altitude Studies

1) Implementation of the recommendations arising out of the seventy-second session of the Indian Science Congress whose focal theme was High Altitude Studies. These were examined by an inter-ministerial task force of the Department of Science & Technology and were forwarded to all the concerned government Departments, Agencies and Research Institutions. A report, outlining the action taken by various Departments was presented. It was noted that some of the recommendations had already been taken note of. Further, the basic recommendation relating to research and development in this area must be taken note of by the government. A National Board on Mountain Research and Technology Development be set up as an autonomous body for overall coordination. It is necessary that a mixture of pure and applied research programmes be undertaken for sustainable development in the high altitude region is necessary.

2) Survey of fauna and flora is essential. The National Board for Mountain Research and Technology Development, when set up, would oversee various aspects of research and priority areas of development, planning etc. This will closely interact with the existing institutions.

As the recommendations of the seventy-second session were summarized, it was strongly suggested that effort would be made to examine them in detail at various levels and set up necessary structures, wherever necessary and also sponsor research projects in different areas.

3) The scope of the high altitude research laboratories at Gulmarg and Nuclear Research Laboratory in Srinagar will have to be enlarged.

4) A network of institutions and some centres be established in high altitude regions to deal with glacier types, early melting of ice, avalanche mapping, land use zoning, medicinal plants, photo-chemical research, etc.

B. Seventy-third Session: Science and Technology in Environmental Management

The Minister of State for Science & Technology inaugurated the Focal Theme Session which was followed by Focal Theme lectures on various facets on environment. The chief points that emerged are:

1) Importance of environmental management and its relevance for the people living in deserts, hills, rural areas, cities both in developed and developing countries.

2) It is not only necessary to manage environment on land and oceans but also the environment of space.

3) Special attention will have to be paid to deserts, forests, agricultural land on account of the new types of the industries and mining activities which are coming up.

4) The activities of the human population on many occasions create problems which will have to be tackled. There is need to have policies and plans. People will have to be educated and science and technology tools developed to manage the environmental problems. As provided in the Constitution of India, and as emphasized by the Prime Minister in his broadcast to the nation on 5 January, 1985, the ecological problems and pollution control activities are of utmost importance before the government. Necessary structures, such as National Wasteland Development Board, Central Ganga Authority etc. have been created. There is a special thrust on maintenance of the ecology.

5) The Seventh Plan Document has also clearly brought out these issues. Therefore, it is well recognized that maintaining the environmental and ecological equilibrium is well enunciated in our policies. The manner and mechanisms in which these policies are to be implemented needs to be evolved. One will have to provide more teeth to the existing laws for better implementation. Science and Technology is crucial in the management of the environment. Use of electronics, biotechnology, new audio-visual means etc. are all important.

6) Science and Technology efforts in frontier areas of genetics, tissue culture, electronics, informatics would be more important for our environmental management, the philosophy of living in harmony with nature has to be inculcated in the human minds. The basic concept of conserving rather than consuming must be popularized and in this process we will have to educate our masses so that the environmental consequences of excessive consumption of the natural resources are made clear to them, proper education provided and awareness created.

7) Various aspects of energy, coal mining, erosion and the use of energy resources in a manner as to protect the environment were brought forth.

8) The national issues which need consideration are creation of general awareness; population control and development of plain and mountainous regions through better science and technology inputs.

9) The Hill Universities will have to be more oriented to the problems of environment.

10) Watershed management, reservoir development and catchment management will need more attention.

11) An overall coordination is important and the problems at the field level will have to be tackled through an integrated approach.

12) In order to meet the targets set by government of bringing 5 million ha under plantation every year, important aspects relating to seedling distribution, raising of plants, maintenance, selection of proper species, soil structure, irrigation inputs, etc. will need to be looked at in totality.

13) The importance of industrial development vis-a-vis the environmental consequences were stressed. The various types of industries which can be a

source of environmental pollution were noted and it was felt that the amount of material produced is much higher than what is consumed.

14) Large inputs of science and technology would be needed. The fast development is affecting the environment; examples quoted were fertilizer industries, dairying, drugs, antibiotics, urbanization, etc. An integrated strategy which will consider issues, such as power generation at coal mines, HVDC transmission, use of fertilizer efficiently, setting up of effluent treatment plants, increased input of research and development, etc.

15) Importance of tapping the non-conventional sources of energy, such as biogas, solar energy, creation of smokeless villages, etc. was emphasized. These devices would be utilized in rural and urban areas as they can be a non-polluting source of energy and environmental hygiene would be an indirect gain from the use of non-conventional energy sources in urban areas.

16) There is a considerable scope in using the modern cell biology in various techniques for assessing the chemo-toxicity which has been a neglected aspect in environmental management, monitoring of the environment, assessment of the environmental status, carcino-genecity of various compounds etc. need to be studied. There are several advantages using the plant systems which need to be carefully gone into. Similarly, cyto-genetic parameters, monitoring of individual chemicals, monitoring the damage on chromosomes, mitochondria, membranes, etc. need to be studied in much greater detail.

17) Areas of research related to energy production and its impact on environment are important. Conservation and efficient use of energy, exploitation of different energy sources, long-term impacts and implication on environment, are important aspects to be studied.

18) The gap between economic planning and environmental research must be bridged.

19) The philosophy to use energy as a resource must be inculcated throughout the country. There should be a general awareness and education among the masses so that the lifestyles would assume a path which is less energy intensive and which will have very little or no harmful effects on environment.

20) The state of environment and development of environmental science and technology in China was also focussed. Some of the issues relating to the characteristics of environmental problems, such as serious damage to natural eco-system, air pollution, water pollution, etc., strategies for conservation of environment and development of science and technology base to deal with environment were important aspects which could be considered for the environmental programmes of a country with similar socio-economic conditions.

Subject Index

Acacia sayel, 195
Acanthus, 123
Acidification, 424, 432
Acid mine drainage, 169
Acid rain, 425, 426, 432, 436
Acoustics, 60, 62
Acquired immuno deficiency syndrome (AIDS), 260
Aegialitis, 123
Aegiceras, 123
Aerosols, 80
Afforestation, 98, 212, 399, 413
Agriculture, 13, 97, 141, 205, 209, 365
Agri-silvi-pastoral model, 14, 21
Agroecosystems, 168
Agro-forestry, 14, 159, 188, 194, 212, 413, 414
Agro-forestry-silvo-pastoral system, 212
Agropyron, 170
Air pollution, 88, 417
Air pollution modelling, 28, 32
Alfalfa mosaic, 153
Alkalinity, 413
Allelopathic, 118
Allium system, 229
Ames test, 229
Analysis of variance, ANOVA, 245
Anopheles maculatus, 265
Anthropogenic, 33
Anthropology, 255, 470
Antiferrodistortive, 72
Apnolic dive, 321
Apple mosaic, 153
Aqueous phase diffusion coefficient, 39
Arabidopsis, 230
Arabis mosaic, 153
Arable land, 188
Archaeology, 255, 470
Aridity, 403, 409
Asbestosis, 37
Asbestos, 38
Ascaris, 258
Asian flu, 261
ASEAN Expert Group on Environment (AEGE), 421
Atherosclerosis, 36
Atomic Energy Commission, 4
Atrophy, 287
Aural barotrauma, 325
Avicennia marina, 123, 129
Axons, 284
Azolla, 150
Azotobacter, 110

Bacillus polymoxia, 110
Bacteriological warfare, 57
Barani Area Development Agency (BADA), 413
Barley yellow dwarf, 153
Bradycardia, 326
Bastar, 6
Benzene, 7
Benzene hexachloride (BHC), 437
Bhakra, 9
Bhopal, 16, 262
Bhopal gas leak, 37
Biochemical oxygen demand (BOD), 16, 90
Biofertilizers, 109, 114, 150
Biogas, 17, 345, 372, 419
Biological diversity, 15, 460
Biological pesticides, 149
Biomass, 17, 21, 114, 130, 191, 345, 350
Biomethylation, 81
Bioorganic, 89
Biosphere, 81, 256, 261, 303
Biosphere reserves, 13, 15, 32, 70, 154, 460, 467
Biotechnology, 11, 13

Biotic, 117, 256
Blue green algae, 152
Blue revolution, 7
Botanical laser, 154
Brahmaputra, 204
Briquetting, 436
Bronchospasm, 293
Bronze, 27
Bruguiera, 124, 129
Byssinosis, 298, 380

Cadmium, 78, 81
Cajanus cajan, 189
Carbon dioxide, 88, 327, 425
Carbon disulphide, 380
Carbonmonoxide, 32, 33, 75, 88
Carcinogenecity, 228
Cardiovascular, 36
Catchments, 22, 209, 210, 217
Carrying capacity, 11, 24, 224
Caustic soda, 385
Cell biology, 228
Cell membrane, 238
Central Forestry Commission, 221
Cerebellum, 286
Chamaegigas intrepedus, 118
Chemical oxygen demand (COD), 436
Chemotransmitters, 286
Chloralkali, 79, 298
Chlorine, 380
China, 414, 431
Chipko movement, 197, 213, 430
Chranosomal aberrations, 231
Cistron, 229
Climate, 391
Cloning, 153
Coal, 80, 380
Command area, 217
Commission on Ecology Working Group, 122
Communication, 365
Conductivity, 238, 240
Conservation of biological diversity, 458
Conservation and development corps (CDC), 22
Conservation, 8, 13, 15, 22, 98, 132, 153, 209
Conservation forestry, 13
Coolie anaemia, 83
Coral reefs, 404
Council of Environmental Quality (CEQ), 23
Crop land, 13, 21
C.T. Scan, 286
Crustaceans, 130
Cropsis aculeata, 118, 122
Cytochromes, 82

Damodar, 203
Darey's law, 37
Decompression sickness, 330
Deforestation, 8, 98, 157, 162, 305, 409, 448
Degradation, 205, 305
Degradable organic materials, 416
Dendrites, 283
Dentrification, 434
Desalination, 86
Desulphurization, 434, 436
DNA, 148, 153
Diabetes, 263
Diathermy, 242
Diatoms, 135
DDT, 89, 260, 261, 380
Dieldrain, 89
Dielectric, 240
Differential absorption lidar, 89
Dinitrophenol, 123
Diode lasers, 89
Diptheria, 259
Dissociation curve, 42
Dissolved solids, 416
Detoxification, 229
Dolphins, 321
Dosimetry, 243
Down's syndrome, 241
Drosophila, 229

Eastern Ghats, 394
Eco-aids, 419
Eco-degradation, 10, 13
Eco-development task forces, 413
Ecological compatability, 18
Ecological security, 13, 210
Ecological succession, 167, 168
Ecological sustainability, 153
Economic and social Commission for Asia and the Pacific (ESCAP), 401, 402
Economic Commission for Asia and the far East (ECAEF), 402
Ecosystems, 21, 85, 163, 305
Ecosystem restoration, 467

Ecotypes, 186, 195
Effluents, 78
Electrodialysis, 86
Electro-optic, 71
Electro pollution, 234, 242
Encephalopathy, 286
Emissions, 16, 75
Energy, 335, 342, 365
  Coal, 338, 343
  Electricity, 343
  Gas, 338
  Geothermal, 17, 339, 351
  Hydro carbon, 342
  Natural gas, 342
  Nuclear, 339
  Oil, 338
  Plantations, 350
  Soil, 339
  Wind, 339
Environmental data base, 467
Environmental crisis, 306
Environmental education, 19, 309, 310, 468
Environment, industrial, 374
Environmental impact, 234
Environmental law, 19
Environmental management, 8, 10, 48, 303, 309, 310, 467
Environment models, 60
Environmental monitoring, 408
Environmental policy, 24
Environmental Protection Agency (EPA), 23
Epidemiology, 55, 59, 282
Escherichia coli, 153, 243
Estuaries, 122
Ethylene diamine tetracetic acid (EDTA), 90
Eucalyptus, 14, 189, 190, 195, 212, 396
Eukaryotes, 229
Eutrophication, 434

Ferridoxins, 82
Ferrodistortive, 72
Ferroelectricity, 71, 72
Firewood, 192, 193
Fishery, 370
Fish protein concentrate (FPC), 208, 373
Flagellates, 135
Floods, 22, 206
Fluid dynamics, 36
Fluid pressure, 37
Fluoride, 85
Fodder, 17, 107, 159, 185, 193, 211
Food, 17, 159, 185, 210, 211
Food security, 427
Forest biology, 184
Forest land, 223
Fossil fuels, 165
Fruit fly, 260
Fuel, 17, 159, 185, 210, 211

Gamma amino butyric acid (GABA), 328
Global atmospheric research programme (GARP), 29
Ganga, 203, 204
Ganga action plan, 17
Gasoline, 80
Gastroenteritis, 259
Gaussian plume, 33
Genetics, 59
Genetic conservation, 153
Genetic engineering, 13, 146, 350, 428
Genetic toxicology, 249
Geographical, 304
Germplasm, 153, 186
Goitre, 286
Grassland, 13, 21, 185, 205
Grazing, 187, 193
Green manures, 113
Green revolution, 6, 89
Guanting reservoir, 435
Gullying, 225
Gypsum, 380, 425

Hazardous substances, 24
Heavy metals, 230
Helium, 321, 329
Hepatitis, 266
Heterosis, 147
High altitude studies, 473
Himalayan Institute of Environment and Development, 24
Himalaya, 203, 209
Hirakund, 211
Hiroshima, 262
Histidine, 229
Histochemical, 228
Homoaquatics, 321
Housing, 365
Huairiver, 434
Human settlements, 18, 305

Hybridoma, 153
Hybrid vigour, 147
Hydrocarbon, 418
Hydrocephalic, 263
Hydrodynamic, 18
Hydrogen, 329, 330, 350
Hydrogen economy, 351
Hydrogen energy, 351
Hydropower, 348
Hydrosphere, 303

Indian Council of Medical Research (ICMR), 276
Illepe, 195
Immunology, 11
Impact assessment, 8, 23
Incineration, 418
Indonesia, 405
Indus, 204
Industrial development model, 21
Industrial forestry, 14
Industrial growth, 375
Industrialization, 305
Infant mortality, 276
Influenza, 261
Infrared, 72, 73
Instrumentation, 71
Integrated land use, 458
Integrated land use planning, 12
Intercropping, 111
Interferometers, 75
International Environmental Educational Programme, 312
In vitro, 152
IRDP (Integrated Rural Development Programme), 362
Iodine deficiency, 285
Irrigation, 16, 209, 365

Jaundice, 259
Jhumming, 398

Karyotype, 231
Khadi and Village Industries Commission (KVIC), 364
Kosi, 203, 394
Kulum grass, 412

Lagoons, 122
Land capability, 24
Land rehabilitation, 174
Landscapes, 22
Landslides, 206, 215
Land use, 165, 186, 204, 214
Land use survey, 12
Lasers, 71, 73, 75, 76
Laterites, 100
Lead, 78, 80
Legislation, 221
Legumes, 113
Lethium, 339
Leucocytes, 239
LIDARS, 76
Limnodrilus hoffmeisteri, 135
Lipoproteins, 36
Lithosphere, 303
Liverstock, 13, 204
Logarthims, 55
Logging, 187
Lotus, 16
Lowland, 215
Lymphocyte, 230

Magnetohydrodynamics, 349
Mangrove, 122, 130, 403
Mahua, 192
Mathematics, 468
Mathematical modelling, 27
Measles, 259, 263
Medical, 320
Mercury, 78, 79, 80, 298, 380
Mesolithic, 264
Messenger RNA, 243
Meteorological, 40
Methyl ammonium aluminium alum, 73
Methyl ammonium chrome alum, 73
Methylisocynate, 38, 229, 387
Metropolitan, 279
Microbiology, 59, 276
Microchemical, 276
Microclimate, 22
Microearthquakes, 62
Microhydel, 17
Micronucli test, 230
Micronutrients, 105
Microorganism, 234
Microwave, 234
Mishimi Hills, 397
Mimic radiation, 228
MINAS, 16
Mined ecosystem, 167
Mining ecology, 173

Model Conservation Bill, 221
Mongols, 263
Moist deciduous, 189
Molluscs, 130
Monitoring, 228, 231
Monoclonal, 153
Moroculture, 395
Monsoon, 28
Montane, 204
Moringa oleifera, 189
Mulch, 192
Multiple land use, 173
Mumps, 263
Municipal health, 280
Mutagenecity, 228
Mutation, 57, 229

Nagasaki, 262
Namdapha, 397
National Commission of Agriculture, 214
National Conservation Strategy, 459
National Land Resources Conservation, 214
National land use, 214
National parks, 13, 15
National Rural Development Programme, 362
National Security, 20
National Resource Monitoring, 408
Natural wastage, 60
Neanderthal, 264
Neolithic, 264
Neonatal, 286
Neohatal mortality, 276, 286
Neon, 329, 330
Neurological, 286
Neurons, 284
Nuclear energy, 349
Nutrition, 283
Nitrogen, 100, 329
Nitrogen fixation, 150
Nitrous oxide, 261
NMC (National Meteorological Centre), 29
Noise, 60
Noise pollution, 60
Non-conventional energy sources, 345
Non-polluting renewable energy system, 17
Non-renewable sources, 17, 21
Nitrogen oxides, 88, 380, 418, 432
NTA (Nitrilotriacetic acid), 90
Nutritional security, 20

Ocean, 17, 61, 351
Oceanic, 27, 28
Occupational diseases, 260
Occupational hazards, 375
Occupational health, 379
Oikos, 20
Oil refinery, 392
Oil seeds, 142
Organic, 417
Organic recycling, 114
Organic manures, 107, 113
Organophosphorus pesticides, 380
Orinthologists, 52
Orinthology, 392
Oxygen, 328
Ozone, 75, 261

Palaeolithic, 264
Papua New Guinea, 405
Parathian, 380
Particulate, 78, 80, 88, 89, 418, 432
Peacock, 16
Pearl, 320
Peptidases, 82, 89, 432, 437
Pesticides, 78
Phenomenology, 276
Philippines, 405, 414
Phosgene, 229
Phosphorus, 100
Photo-insensitive, 142
Photosynthesis, 22, 99, 125, 130
Photovoltage, 371
Phytoplankton, 85
Physicochemical, 117
Piezoelectric, 71
Pines, 190
Pinworms, 258
Pipal, 16
Plant breeding, 148
Plant protection, 105
Plasmodium flaiparum, 259
Pneumoconiosis, 267
Polioxmyelitis, 263
Pollutants, 32, 75
Pollution, 8, 10, 16, 55, 60, 78
Pollution monitoring, 409
Polychlorinated biphenyls (PCB), 262
Population, 6, 11, 22, 204, 275, 374, 402, 405, 442

Postnatal, 284
Potassium, 100, 123, 124
Priority areas, 458
Primary Health Centres, 279
Productivity, 130
Project Tiger, 424
Protected areas, 15
Protein-caloric-mainutrition, 285
Protoplast, 147, 148
Provenances, 185
Proxemics, 315
Pseudomonas striata, 110
Public health engineering, 280
Pyroelectric, 71
Pyrolysis, 418

Radiation, 74, 117, 234
Radioactive, 5, 53, 228, 344
Radiofrequency, 243
Radiometers, 75
Ramganga, 210
Reafforestation, 188, 191, 396, 413
Reclamation Act, 168, 173
Recombinant DNA, 59, 147, 153
Recommendations, 468
  Agricultural science, 470
  Anthropology, 470
  Archaeology, 470
  Botany, 469
  Chemistry, 469
Educational science, 471
  Engineering, 471
  Entomology, 470
  Fisheries, 470
  Geography, 469
  Mathematics, 468
  Medical & Veterinary Science, 470
  Physics, 469
  Physiology, 470
  Psychology, 471
  Statistics, 469
  Zoology, 470
Recycling, 18, 24
Refrigerator, 358
Regeneration, 187, 192, 244
Rehabilitation, 163, 171
Remote sensing, 71, 75
Renewable energy sources, 344
Republic of Korea, 405
Research, 216
Research needs, 467
Research training, 184

Saccharomyces cerevisiae, 243
Safety statutes, 375
Sal, 189, 192
Salinity, 122, 403, 413
Salmonella typhimurium, 229, 258, 260
Salinization, 96, 305, 432
Sanctuaries, 15
Sanitary land fill, 418
Sanitation, 18, 365, 366
Savannahs, 158
Scarlet fever, 263
Scavenging, 418
Scrophulariaceae, 118
Scrubbers, 418
Sedimentation, 206, 404
Selenium, 96
Semi-evergreen, 189
Sesbania rostrata, 150
Sewage, 83
Sewage sludge, 107
Sewerage, 18
Shifting cultivation, 205
Shivalik, 212
Shrimps, 130
Silent valley, 15, 23, 424, 459
Silicosis, 260, 267, 298, 380
Siltation, 394, 404
Silviculture, 158, 187
Singapore, 405
Singrauli, 354, 355, 356
Sister chromatid exchange (SCE), 231
Slash-and-burn, 158
Slum, 18, 275, 276
Sludges, 416
Smallpox, 259, 263
Small Farmer's Development Agency (SFDA), 363
Social forestry, 13, 184, 186, 187, 193
Sociobiology, 59
Sodium, 123, 124
Sodium chloride, 84
Sodium trihydrogen selenite, 73
Soil, 22, 95, 169
  Conservation, 9
  Erosion, 6, 191, 305, 403, 432
  Environment, 95
SOILWATCH, 210
Solar cookers, 346, 371
Solar distillation, 86

Solar energy, 350, 371
Solar photovoltaic, 347
Solar thermal energy, 346
Solid waste, 432
Solid waste management, 417
Somaclonal, 149
Songhua river, 437
Sonneratia, 129
Source inventory, 33
South Pacific Regional Environmental Programme (SPREP), 421
Spectrometers, 75
Spectroscopic, 71, 72, 73
Statistics, 50
Stochastic, 51, 58
Storm surge, 28, 29
Stress, 116
Stressed habitats, 116
Subabul, 189, 195
Sulphur dioxide, 32, 33
Surface mining control, 168, 173
Sustainable development, 8, 10
Synapse, 284
Syphilis, 259, 263

Taj Mahal, 392, 425
Tbilisi conference, 312
Teak, 189
Technologies, 348
Temperate, 204, 395
Teratogenic, 263
Terracing, 209
Terrestrial Ecosystem, 403
Territoriality, 315
Thailand, 44
Thermal, 325
Thiamine, 286
Thermodynamic, 47
Tiger, 16
Timber, 192, 210
Tissue culture, 147, 350
Topography, 112
Top soil, 13, 98, 261
Toxaemias, 263
Toxicity, 81, 228
Toxic gases, 32, 78
TPP (Sodium tripolyphosphate), 90
TCDD (Tetrachlorodibenzo-n-dioxin), 90
Trace elements, 82
Tradescantina, 230
Transportation, 365, 366
Tribal, 255
Trigonella acculate, 118, 122
Tritium, 339
Tropical forest, 157, 395
Tropical humid forest, 395
Tropical rain forest, 266

Ultrafiltration, 123
Ultraviolet, 75
UNESCO, 311
UNEP, 311
United States, 264
Upland, 215
Upper palaeolithic, 264
Urban, 22
Urbanization, 275, 305
Urban Basic Services Programme, 281
Urban crisis, 278
Urban health, 275
Urban housing, 278
Urban policy, 281
Urban services, 279
Urban wastes, 348
Usar, 191

Vegetation, 112, 169
Vehicular traffic, 33
Vertigo, 325
Virology, 59
Viscose rayon, 385
Viscosity, 37, 242
Viviparous, 122

Wastelands, 188
Wasteland Development Board, 214
Water, 16, 22, 99
Water conservation, 12, 24
Water pollution, 16, 83, 414
Watersheds, 12, 22, 203, 205, 209
Water logging, 403
Water tabb, 112
Water vapour, 39, 75
Wetlands, 142, 426
Wet scrubbers, 81, 89
White revolution, 7
Wilson disease, 83
Wind, 17, 117
Wind energy, 347
Wind power, 351
Woodland, 13, 21

Woodland and vegetation, 458
Work capacity, 290
World commission, 423
World conservation strategy, 423

Xiang river, 437
Xylocarpus granatum, 129

Yaer lake, 436
Yantze river, 437
Yeast, 229
Yellow river, 434

Zinc, 109

OXFORD & IBH PUBLISHING CO. PVT. LTD.
New Delhi Bombay Calcutta